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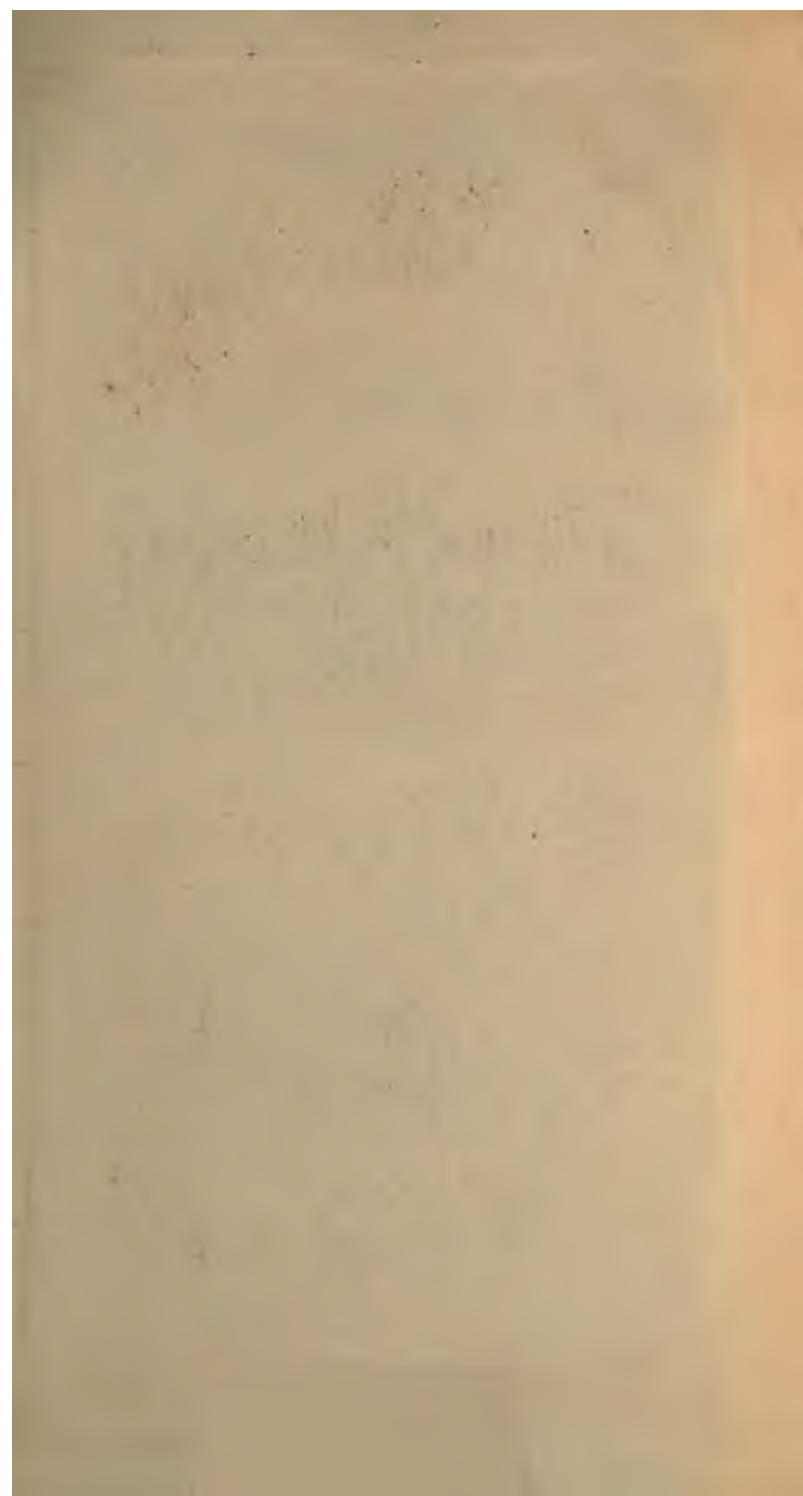
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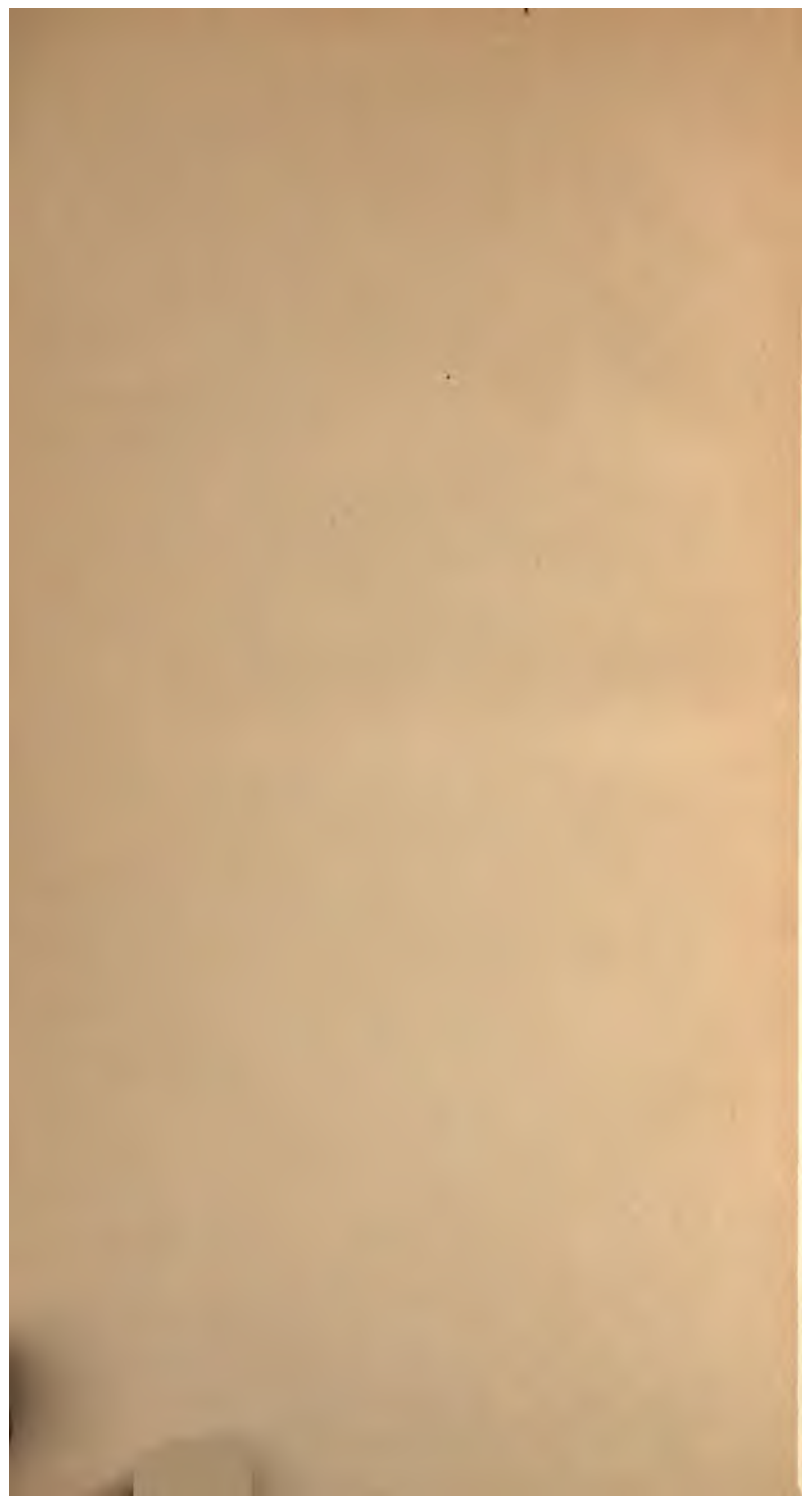
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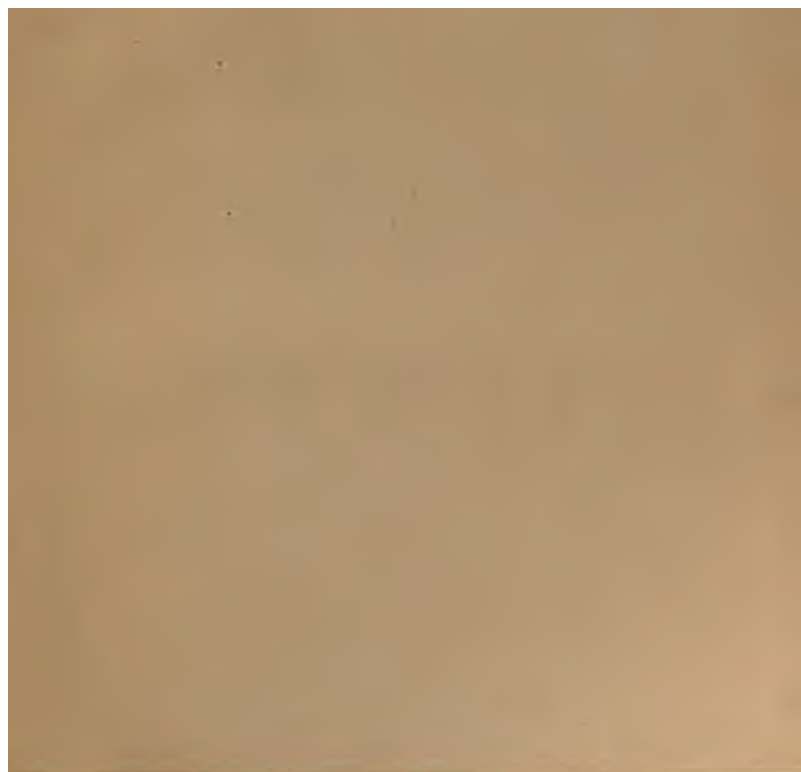


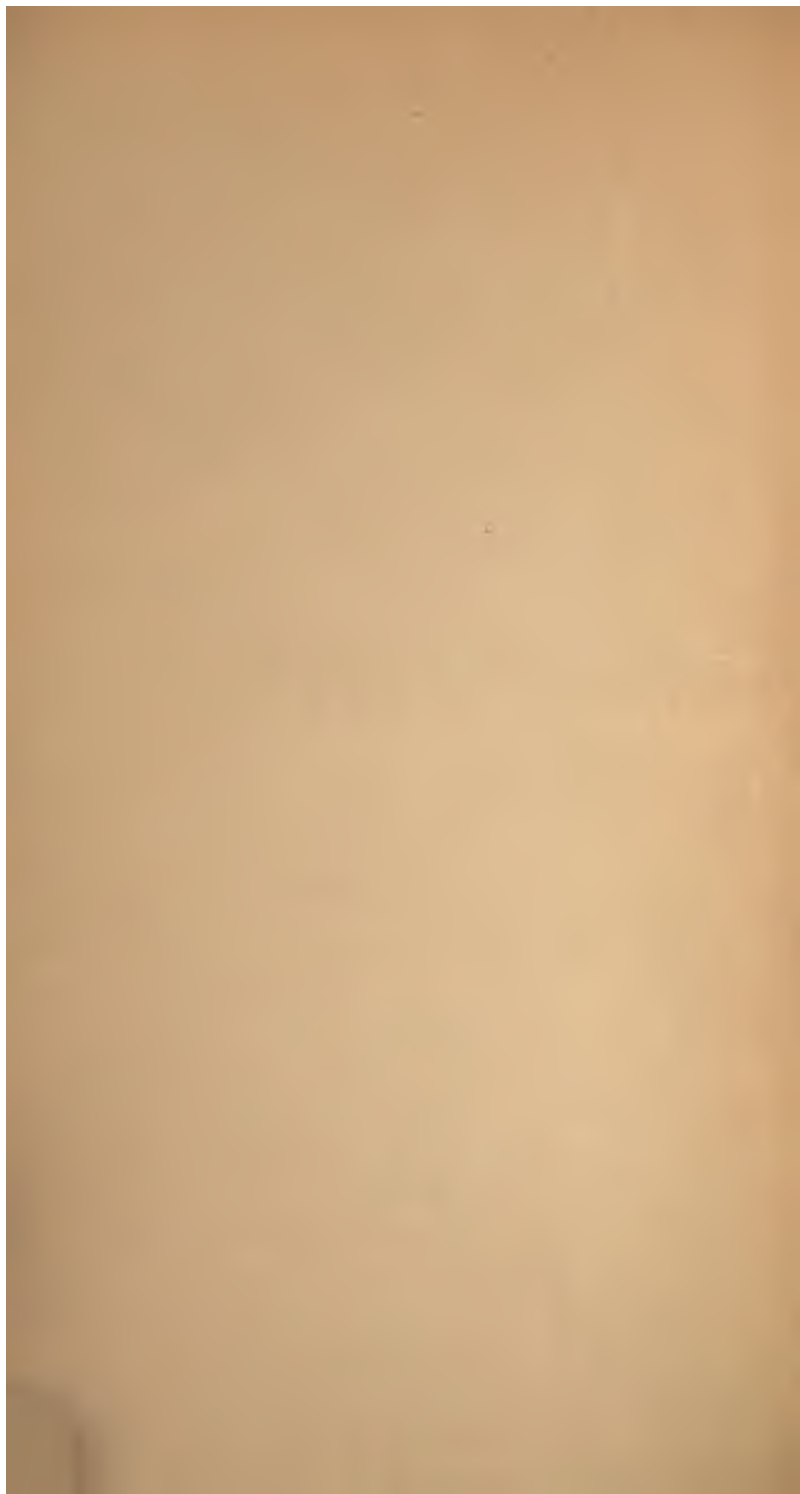
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CHEMISTRY
APPLIED TO
A R T S
AND
MANUFACTURES.

BY M. J. A. CHAPTAL, ✓

MEMBER AND TREASURER OF THE FRENCH SENATE ;
GRAND OFFICER OF THE LEGION OF HONOUR ;
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IN FOUR VOLUMES.

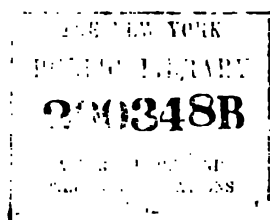
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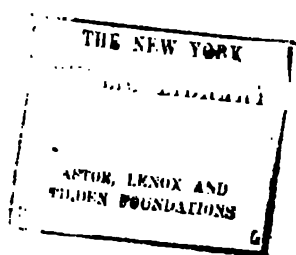
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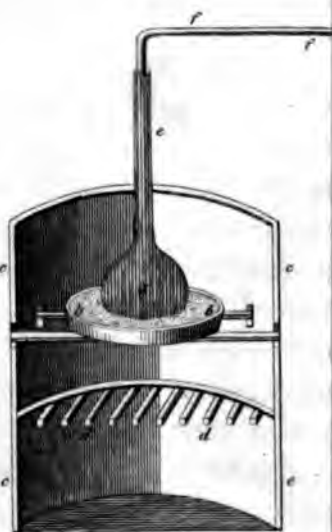
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CHEMISTRY

APPLIED TO THE ARTS.

CHAPTER V.

The acids.

ALTHOUGH analysis has discovered the constituent principles of most of the acids, and we might accordingly rank them among the compound bodies, yet we think it right to introduce them here, because they are the most powerful, and the best known agents in our chemical operations ; and also because some of them have not yet been decomposed, and almost all of them in their combinations with other bodies act like simple substances.

It has been generally agreed upon to describe by the appellation of *acids*, all bodies which possess the following properties :

1. What is generally characterized by the word *sour*, in ordinary conversation, is known by the name of *acid* in the language of chemistry: thus *sourness* and *acidity*, *sour* and *acid*, are synonymous terms.

2. The affinity of water with the acids is very striking: the solution of most of them is effected in it with heat, and all of them acquire fixation by these means: even those which are very elastic in their nature, such as the fluoric, muriatic, and carbonic acids, lose their elasticity the instant they are put in contact with water, and afterwards make a remarkable resistance to their being volatilized.

3. The acids redden some blue vegetable colours, such as those of turnsole, mallows, violets, &c.

We may either employ the flower of the violet or its infusion; but in the latter case, the base of the petals, which is yellow, must be rejected, as without this precaution the blue of their tops and the yellow of the base would form green.

What is called *syrup of violets* is also employed; care is taken, however, to dilute it

before using it, as otherwise the concentrated acids reduce it to a spongy charcoal, without reddening it sensibly.

The blue of turnsole is still more sensible than that of violet: its infusion on paper coloured with it is made use of. The infusion should be weak and light; it appears red or violet coloured when it is too strong*.

* It was formerly believed that the turnsole known in commerce, was the colouring part of the *turnsole cloths* prepared at Grand Gallanges, near Montpellier, and made use of in Holland. It was thought that the Dutch alone were in possession of the secret of extracting this colouring principle, and of mixing it with an earth, in order to form the *turnsole cakes*.

I am the first who has been able to put an end to this mistake:

1st, The blue in the turnsole cloths, seems to be so transient and so little abundant, that I cannot conceive how the Dutch could extract it to any advantage.

2d, The most saturated infusion of the colouring principle of these cloths, did not at all colour the earthy substances upon which I tried to precipitate it.

3d, I know, besides, that these cloths were sent to cheese dealers, who made use of them in their manufactories.

4th, Analysis demonstrated to me the existence of potash and carbonate of lime in the turnsole cakes, and at the

I have made use of an infusion of the blue flowers of the iris to advantage ; it reddens

same time a colouring principle much more abundant than that which the cloths contain.

From all these facts, I concluded that the blue in the turnsole cakes was not extracted from the cloths of Grand Gallanges, and I endeavoured to make it by means of the lichens employed in the composition of the dye called *orseille*.—I was induced to try these lichens for the following reasons :

The *lichen parellus*, or *parelle*, of Auvergne, which grows in abundance upon the rocks in the departments of Pay-de-Dome, Cantal, Lozere, Aveyron, Ardecbe, Isere, Drome, &c. and which the English bring from the shores of Italy, is employed in the formation of *orseille* : it is in the department of Pay-de-Dome and at Lyons that this branch of industry is chiefly established. This violet paste is made in these places by macerating the lichen with urine and lime. As the colour of *orseille* appeared to me to be very similar to that of turnsole, and as it only differed from it by the red which, combined with blue, forms violet ; as, on the other hand, I found on an analysis of turnsole, a little potash, which does not exist in *orseille*, I concluded that potash might be employed to advantage when opposed to the development of the red colour. My suspicions were very soon confirmed by actual experience.

I fermented the *lichen parellus* with urine and pearl-ashes, in different proportions : I soon saw by my first experiments, that in order to have very distinct results, the

with the acids, and forms a green with the alkalis. In the South of France this infusion

lichen should be employed in a sufficiently great quantity; and each of my experiments was made with six pounds of lichen.

At first I mixed alkali, urine, lichen, and chalk; and I endeavoured to make them ferment together, but by this method I merely obtained a paste of a violet brown, and very disagreeable to look at.

I then mixed the pulverized lichen with the alkali of pearl-ashes: I facilitated the fermentation by means of urine; and I obtained a blue paste inclining to violet, but which I made use of to great advantage in all the experiments of my laboratory, as it became an agreeable blue when diluted in water.

I observed,—1st, That the lichen must be chosen with great care, and bruised properly.—2d, That the alkali ought to be mixed in equal parts with the lichen, and that pearl-ashes ought to be preferred.—3d, That the urine should be added in small quantities at a time, as there is need for it; too much or too little prevents the experiment from proceeding.—4th, That the most convenient temperature is between 15 and 25 degrees of Reaumur.—5th, That the paste generally assumes a red colour, which disappears of itself, or which may be corrected by adding a new quantity of alkali or of well putrified urine.

I confess that the turnsole I manufactured was inferior to that known in commerce; it was always impossible to

is employed in order to change into a blue colour the syrup of violets.

deprive it of its reddish cast, which disappeared indeed in solutions of it, but which did not permit me to compare my production with the Dutch article. This induced me to detail my process as often as new experiments or chance happened to present more satisfactory results. In my Elements of Chemistry, under the article acids, these details will be found.

The invasion of Holland has made me acquainted with the artists of that industrious nation, and we may now inspect all the secret processes which have hitherto enriched that country. The secret of making turnsole is one of the number, and the details which have been given us may be reduced to what follows:—They confirm my ideas upon the constituent principles of turnsole, and upon the method of manufacturing it. The only difference is in the nature of the lichen employed. It is the *lichen roccella* of the Canaries or Cape Verd, or *Swedish moss*, which the Dutch use. It is the same *lichen* of the Canaries which they employ in the manufacture of vegetable *orseille*, or Canary *orseille*. Linneus has thus described it: *lichen fruticulosus, solidus, aphyllus, subramosus, tuberculis alternis*.

These plants are dried, cleaned, and afterwards pulverized in a mill: the powder is passed through a sieve, and what is not sufficiently bruised is put into the mill again: The powder is then put into a trough 12 feet long by 3 high, and two feet broad at the bottom. It is wider at the top. Half the quantity of pearl-ashes well bruised, is then

4. What particularly characterizes the acids, is the powerful action they exercise upon almost all bodies : they tend incessantly to combine with other bodies, and they lose their acid properties in the combinations : they form neutral salts with the alkalis, the earths, the metals, &c. : they unite with oils ; they

mixed with the lichen powder. The mixture is made with wooden spatulas.

The mixture is then moistened with human urine : that of animals does not contain enough of ammonia. When fermentation is excited, more urine is added in the room of what has evaporated.

As soon as the mass has assumed a red tint, it is transferred into another trough like the former : more urine is then thrown in ; it is stirred, and some days afterwards it assumes a blue tint. This paste is then divided into buckets resembling barrels cut in two ; a third part of excellent potash is then mixed with it, and urine is again thrown upon it.

This division moderates the fermentation and allays the heat, which, if too great, would alter the quality of the paste. This period requires much care.

The paste now assumes a magnificent blue colour.

It is mixed with chalk to diminish the price of it, and placed in small oblong cases ranged on an iron plate ; these cases are then put upon fir boards, and placed to dry in an airy granary.

are decomposed by acting upon vegetables, &c. &c. It was this great affinity of the acids which induced the celebrated Newton to give them the appellation of "*bodies which attract and which are strongly attracted.*" It is owing to this great affinity of the acids that they are rarely found in a free state. It is this same affinity which has caused them to be employed by chemists under the name of re-agents, or agents of composition and decomposition, of union and disunion, &c.

With the exception of the sour taste, there are bodies which possess all the properties of acids: for instance, sulphuretted hydrogen dissolved in water, reddens turnsole tincture; it combines with the alkaline and earthy bases; it decomposes soap, and takes the place held by the oil among the alkalis; it precipitates in a great proportion the sulphur from the solutions of sulphurets of potash or of lime, and it tends to form a triple combination with what remains.

The acids in general do not seem to be any thing else than burned bodies: Scheele had presented us with this fact previous to the year 1775, when he said, in the second edition of

his Chemical Treatise upon Air and Fire :—
“*It seems probable to me that all the acids owe their origin to the air of fire.*” Lavoiser has left no more doubt as to this assertion ; he has proved the existence of the *air of fire*, or *oxigen gas*, in all the acids he was able to analyse.

It was after the result of the analysis of some acids, all of which presented *oxigen* for their base, that it was regarded as the only *acidifying* principle. M. Berthollet does not think proper to admit a doctrine so absolute. 1st, Because the analysis of the Prussic acid furnished him with no oxygen ;—2d, Because sulphuretted hydrogen unites all the acid properties, without having oxygen for its base ;—3d, Because it is presuming too much to suppose that all the acids which have not yet been decomposed must necessarily have the same base with those which have been actually analysed.

The substance to which oxygen is united in the known acids, is called *the radical of the acid*. Thus carbon, sulphur, and phosphorus, are the radicals of the acids which bear their names.

Oxygen is not always united to one rad-

cal alone: the acids have sometimes two radicals, as we see in the vegetable acids; and sometimes three, as in those which belong to the animal kingdom.

It follows that the acids vary, not only in the number and the nature of their radicals, but also in the proportions which exist between all their principles.

There is, however, a point of saturation between the acidifying principle and the radical, which forms the true state of an *acid*; and it is in this state that it is most generally known in commerce and in the shops. It has been even agreed, in laying the foundation of the new chemical language, that by varying the termination of the name of the acid, we should express the proportions which exist between the principles: thus, the termination in *ic*, is an exact combination; whence we say, the *phosphoric, nitric, and sulphuric acids, &c.* The termination in *ous*, expresses the predominance of the radical over the oxygen; as *phosphorous, nitrous, sulphurous, &c.* We accompany the denomination of the acid with the epithet *hyper-oxygenated*, when the oxygen is in excess.

By following up these first laws of the che-

mical nomenclature, denominations have been contrived, particular and generical, to each of the combinations formed by the acids, at these different degrees of saturation ; and the words *sulphates*, *sulphites*, and *hyper-oxygenated sulphates* ; *nitrates*, *nitrites*, and *hyper-oxygenated nitrates*, express the compounds which are formed by the *sulphuric* and *nitric*, the *sulphurous* and *nitrous*, the *hyper-oxygenated sulphuric* and *hyper-oxygenated nitric* acids.

It often happens that an acid changes the proportion of its elements, and passes through these different states in acting upon the substances presented to it, in such a manner that the combinations which result from it no longer present the acid in its primitive state. Its decomposition is sometimes so complete, that the radical is set free, and the oxygen enters by itself into new combinations.

The principal character of an acid is to saturate an alkali completely, in such a manner that the compound which results from it no longer presents any acid or alkaline properties.

All the acids do not possess this virtue in the same degree ; and it is by this variety of

power upon one and the same quantity of alkaline base, that we are able to measure the affinity of the different acids. An acid is therefore so much the more powerful, in proportion as an equal weight of it can saturate a greater quantity of alkali.

It is necessary to distinguish carefully the power of an acid from its energy: the acid may be diluted in a greater or less quantity of water; and consequently the quantity of acid which exists in the sphere of activity may be more or less great, and the action more or less weakened, which may vary the energy of the acid without altering its power in the least, which is calculated upon the total effect of the mass.

SECTION I.

Of the carbonic acid.

The carbonic acid is the most extensive of all the acids. It exists in the atmospheric air, from which it seems to be inseparable, since we find it mixed with it, and nearly in the same proportions, at all heights: it forms one of the principles of lime-stone, and of the

calcareous mass which covers a great part of the globe : it is produced daily by the decomposition of animal and vegetable matters ; by respiration, combustion, fermentation, &c.

We find this acid in three states : in the state of gas ; in solution in water ; and in combination with the earths, the alkalis, &c.

The gaseous carbonic acid exists in the atmosphere, where analysis has found it in the proportion of 2,00, and in all places where abundant beds of vegetable matters are decomposed : it very often escapes from the interior of the earth, where it is produced by similar causes, and occasions phenomena which were a subject of astonishment to naturalists and to the common people, until the period when chemistry spread its light upon them : it was thus that the *Grotte-du-Chien*, near Naples, the *Puy-de-la-Poule*, at *Neyrac*, in the Vivares, excited astonishment and admiration by the property they possess of extinguishing lighted bodies, and of suffocating animals when plunged into them.

Frequently the bubbles of carbonic acid, in coming from the earth, pass through masses of water, and produce in it a continual boiling: the

water is then impregnated with acid, and the overplus mixes with the atmospheric air to which it communicates noxious qualities. Marshy countries present several examples of this nature: the Lake Avernus, where Virgil has placed the entrance of the infernal regions, and above which birds dare not fly with impunity; the marsh of Masillargues, known by the name of the *Boilers*; the Bouldou-de-Perols, near Montpellier, and other places which it is needless to mention, present phenomena of this nature.

Gaseous carbonic acid, heavier than atmospheric air, and keenly dissolving in water and combining with carbon, lime, the alkalis, &c. is naturally precipitated from the bosom of the atmosphere and deposits itself, dissolves, or is combined with the bodies which exist on the surface of our globe: it is thus that we may draw it down from the bosom of the atmosphere, in order to separate it afterwards, and to set it free by the processes with which chemistry furnishes us.

When carbonic acid is free from every mixture, or nearly so, we may easily collect it, and fill vessels with it, which we may carry to a laboratory in order to proceed to a more perfect

examination : it is sufficient for this purpose, to carry into its atmosphere a bottle full of water, and then uncork it in order to pour out the liquid it contains : it is evident that in proportion as the water escapes, the carbonic acid will take its place ; and upon carefully corking the bottle it may be carried to a distance. Lime, lime-water, and the pure alkalis, placed in vessels and exposed to the air in an atmosphere of carbonic acid, are speedily combined with it, and form carbonates which may be easily decomposed ; which also furnishes a method not only of purifying an unwholesome place from the acid which infects it, but of analysing and determining the proportion and the nature of the gaseous mixtures.

When carbonic acid is dissolved in water, and constitutes the numerous class of mineral waters which are said to be *acidulated*, we may separate it from them—1st, By the agitation of the liquid in a bottle filled with two-thirds of it, and to the neck of which a moistened bladder is adapted in order to receive the gas as it is liberated. This process, proposed and executed at first by M. Venel, is very imperfect. 2dly, By the distillation of a known quantity of this

same water in the pneumato-chemical apparatus, as recommended by Bergman. 3dly, By combining the acid with lime-water, or with pure alkalis, and decomposing them afterwards by fixed acids, such as the sulphuric acid. This last process is the only rigorous one, the two first only furnishing approximate proportions.

It already follows from the principles and methods of analysis we have proposed, that when carbonic acid is naturally combined with a base with which it forms a fixed compound, distillation, and above all, the action of the other acids can separate it and set it at liberty.

Carbonic acid possesses all the characteristic properties of the acids: 1st, It reddens turnsole tincture. 2dly, It saturates the alkaline bases.

It is to Bergman we are indebted for our first knowledge of the acidity of this substance, which he called the *aerial acid*: after him it has been successively described by the names of *chalky acid*, *mephitic acid*, *carbonic acid*, denominations all of them deduced from the nature of its combinations, its effects, or of its radical.

This gaseous acid speedily kills such animals

as are plunged into its atmosphere. Bergman observed, that animals which die of this poison present no sign of irritability from the moment they become lifeless. Before his time it had been observed, that the limbs, when plunged into this acid, are benumbed in it; and perhaps we may refer to this cause the effects of fermented liquors when drunk in too great abundance, and the stupor which is the consequence, as well as the sedative virtue of any antispasmodic potion, the effect of which is merely owing to the disengagement of carbonic acid produced by the sudden mixture of citron juice and *sal absinthii*.

This acid is as little proper for combustion as for respiration: it extinguishes all inflamed bodies which are plunged into it, and its effect upon lighted substances is more rapid than that which it produces upon the respiration of living beings; this supplies a sure method of preserving ourselves against its disastrous effects; for as soon as we suspect the noxious qualities of any atmosphere, from its combination with too great a quantity of carbonic acid, we may ascertain the fact by trying it with a lighted candle, and if it burns, there is no danger to be apprehended to an individual.

The property possessed by this acid, of combining speedily with lime and the pure alkalis, furnishes a method of purifying places which are infected with it: it is sufficient to water or sprinkle the ground and the walls with these liquids, or to deposit them in the inclosure. The effect of pure ammonia, potash, and soda, is so rapid, that we need not slacken our pace in a vault filled with this gas, when these liquors are scattered as we advance.

This gaseous acid is heavier than atmospheric air, which is the reason why it is precipitated into low and deep places: this excess of gravity, causes it to displace the atmospheric air, and in consequence of this, we may pour it out of one vessel into another, and produce effects so much the more surprising to those not accustomed to these phenomena, that this fluid is invisible.

Mr. Kirwan found its gravity, compared with that of atmospheric air, to be at the rate of 68,74 to 45,69, and Lavoisier in the proportion of 69,50 to 48,81. A cubic inch of this gas weighs nearly seven-tenths of a grain under ten degrees of temperature, and at the pressure of 28 inches of the barometer.

It is now beyond doubt, that carbonic acid

is a combination of oxygen and carbon : it is formed in every respect by the combustion of carbon.

Its decomposition is not supported by so great a number of proofs ; we have, however, several direct experiments on the subject. Mr. Tennant, in March 1791, read a memoir to the Royal Society of London, in which he says, that having kept phosphorus and marble in a retort at a red heat, he obtained carbon and phosphoric acid. Mr. George Pearson communicated to the same Society, on the 24th of May, 1792, the following facts : 200 grains of phosphorus and 800 grains of carbonate, heated in a glass tube, gave 32.4 of carbon and phosphate of soda ; carbonate of potash, and the earthy carbonates, furnish results of the same nature ; the alkalis and the pure earths yield no carbon. M. Clouët, on treating iron with carbonate of lime, obtained steel, one of the principles of which is carbon. If from these positive proofs, we pass to the phenomena presented to us by nature, we see that vegetables absorb carbonic acid, when it is presented to them in a small quantity ; that they decompose it ; and that carbon becomes

one of their nutritive principles while oxygen is liberated.

The proportion of carbon, in comparison with oxygen, has been estimated at 12 to 56. Scarcely was this acid known, when physicians began to proclaim its virtues with enthusiasm, and they magnified it into a true polychrest. It has been successively proposed as a solvent for the calculi of the bladder, as a specific against cancer, &c.; and what we see every day, has happened in this case also, viz. after having extolled beyond bounds the properties of a remedy which experience has not confirmed, it is afterwards abandoned without considering what efficacy it really had in cases which were well authenticated. At present, in order to form a rational and very precise idea of the medicinal virtues of this acid, we may consider it in two states—as a gas, and in its state of solution in water. In the first case, it extinguishes irritability, and when judiciously administered, it may form a very efficacious sedative: in the second case, it enters into the class of weak acids, and it may be employed as an antiseptic.

SECTION II.

Of the sulphuric acid.

The sulphuric acid has been known since the fifteenth century : Basil Valentine has mentioned it by the name of *oil of vitriol*, and he informs us that he extracted it from green vitriol.

The characteristic properties of this acid are the following :

1. It reddens strongly the blue vegetable colours, with the exception of indigo, which it dissolves without altering its colour.

2. It is without smell, transparent like water, and unctuous to the touch like oil ; it is this latter quality which has given it improperly the name of *oil of vitriol*.

3. It has a strongly acid and very corrosive taste.

4. It requires, according to Bergman, three times more heat than water does, to bring it to the boiling point : Erxleben has computed this degree of heat at 546 of Fahrenheit, and 228,44 of Reaumur. At this degree of heat it is elevated in white vapours, easily condensed in a

receiver, where they form a very white and pure liquid.

5. It blackens and chars animal and vegetable substances.

6. Its specific gravity is almost double that of pure water, when it is strongly concentrated. It marks 66 degrees in the liquor scales of Baumé.

7. It mixes with water with effervescence: this heat may be carried to 95° of Reaumur, by pouring one pound of acid upon three ounces of water. The mixture of these two liquids does not enter into ebullition, although carried to a degree of heat far above that of boiling water, because it is thicker and less capable of evaporation. But if we plunge a crooked tube into water upon which the acid is poured, the heat excited is in a state fit to boil the water contained in the tube, which then escapes in steam by the two apertures of the tube.

Messrs. Lavoisier and Laplace observed, that during the mixture of two pounds of sulphuric acid of the specific gravity of 1.87056, with one pound and a half of water, both of them at 0, the heat resulting from the combination melted three pounds two ounces and two

drachms of ice, *i. e.* as much ice as produced two pounds five ounces seven drachms and forty-three grains of boiling water.

The properties of the sulphuric acid have rendered it precious in the arts and in the laboratory: on one hand, it has very decided affinities for the different bases; and in this respect it is employed with success to separate and disengage the other acids from their combinations. On the other hand, it is one of the most fixed acids we know; and this quality causes it to be preferred, because in its action, it mixes no foreign produce in the substance displaced or volatilized with its assistance.

This acid is very abundant. By the help of art, we can extract it from its natural combinations, or compose it in every respect, very economically: as it has been known for a long time, its properties and combinations are well ascertained; so that chemists have employed it as one of their most frequent agents.

ARTICLE I.

Processes for manufacturing or extracting the sulphuric acid.

Although the sulphuric acid is formed every day in the different operations which are executed at the surface, or in the interior of the globe, since we every day see metallic alkaline and earthy sulphurets pass to the state of sulphates, this acid rarely presents itself in a free state, while the energy of its affinities engages it in new bases, in order to form neutral salts in proportion as it is developed.

Hitherto, it has been only in the neighbourhood of volcanoes that it has been found free from every combination, or so feebly engaged among bases, that the acid properties predominated. Baldassari observed it in a grotto of the mountain St. Amiato, near the baths of St. Philippi, at St. Albino, and on the lakes of Travalle. He adds, that it exists in these places in the form of efflorescences or separate threads. Vandelli relates, that in the environs of Viterba and Sienna, the sulphuric acid is found dissolved

in water. Dolomieu observed it in a grotto of mount *Ætna*.

It would seem from the observations of naturalists, that almost in every case where this acid was found in a state of efflorescence, it was only sulphur strongly oxydated, such as we find it as sublimed in the apparatus where this acid has been produced by combustion. When we sublime sulphur in order to form what is called *flowers of sulphur* in commerce, we acidulate it slightly, but nevertheless to such a point, that washing it in water does not efface its acid characters.

Thus the existence of the sulphuric acid near volcanoes, and in every place from which sulphurous vapours are continually rising, is not at all surprising.

The sulphuric acid employed in commerce is entirely the produce of art.

We may reduce to the number of two, all the processes made use of for manufacturing this acid: it is either extracted from compounds which present it ready formed, or rather it is formed completely, by the combination of sulphur with oxygen.

composed by heat. Neuman and Baumé were convinced of this, and so am I.

4. The sulphate of lime retains its acid with still more force: and Margraaf himself has seen that it requires the contact of some inflammable matter, to operate the decomposition of this salt; but then the acid is partly decomposed, and reduced to the state of sulphurous acid.

§ II.

Formation of the sulphuric acid by the combustion of sulphur.

We may present oxygen to sulphur in two states: in the state of gas, or in the concrete state.

Every body knows that if we burn sulphur in the atmospheric air, there results from it a very volatile, pungent substance, of a suffocating smell, acid, and susceptible of combination with the alkaline bases.

Stahl, who has made us acquainted, not only with the method of obtaining this acid, but with the nature of its principal combina-

tions, has called it *sulphurous acid*, *spiritus sulfuris per campanam*.

Sulphurous acid is made by the pure and simple combustion of sulphur, or by the desoxygenation of sulphuric acid over the metals, phosphorus, or carbon.

But by these last processes, we rarely have the sulphurous acid very pure; in the mean time the metals decompose water, and hydrogen gas is disengaged, mixed with sulphurous acid.

Messrs. Fourcroy and Vanquelin, to whom we owe a grand work upon sulphurous acid, distil one part of mercury with one part of sulphuric acid: the sulphuric acid which naturally escapes, is received in the water of the first flask, while the sulphurous gas proceeds into a vessel inverted over mercury, or into the water of the second flask, according as we wish to have it in a gaseous or a liquid state.

When it is required to prepare sulphurous acid for the arts, as this degree of purity is not necessary, we distil the sulphuric acid over wood, saw-dust, or cut straw.

The sulphurous acid has a lively and penetrating smell.

It is neither proper for respiration nor for combustion.

Its specific gravity, according to Bergman, is 0,00246; and 0,00251, according to Lavoisier.

The cubic inch weighs 1,508 grains. Its taste is sharp, hot, pungent, acid, disagreeable, burning the throat and provoking cough.

Sulphurous acid decomposes nitric acid, as well as oxy-muriatic acid, and passes to the state of sulphuric acid.

It combines with the alkalis and the earths. Messrs. Berthollet, Fourcroy, and Vauquelin, have published these combinations.

In general, the sulphites have a pungent taste, analogous to that of their acid. They are decomposed by fire; they are changed into sulphat by the contact of the air, or by the action of some acids.

Sulphurous acid is employed in the arts in bleaching silks and some woollen stuffs: bleachers are contented with exposing them moistened, in close chambers, to the vapour of sulphur

in combustion. It would seem that in this operation, the sulphurous acid is decomposed, and that its oxygen greedily absorbs the colouring principle, while the sulphur becomes free.

It is now known that several bodies that are digested over combustible substances abandon the oxygen, which is one of their principles, in order to operate a true combustion. Nitric acid digested over sulphur is in part decomposed; and there results a formation of a small quantity of sulphuric acid.

Scheele announced that the oxy-muriatic acid could not acidify sulphur. Hageman saw, that by directing the vapour of this acid over half a drachm of sulphur, the sulphur becomes fluid, and forms a clear solution which acquires double its primitive weight; but he adds, that the sulphur is only dissolved and not decomposed, because the addition of a little water precipitates it instantly.

On the other hand, M. Guyton Morveau was convinced that sulphur was converted into sulphuric acid by the decomposition of oxy-muriatic acid, without the assistance of heat.

In consequence of this difference in their results, I had recourse to experiments myself, and the following results presented themselves to my view.

1st, Oxy-muriatic acid poured in a state of vapour upon sulphur in a state of minute division, dissolves it gradually, and flies off with it in the state of a white vapour, the smell of which, when respired at a certain distance, resembles that of some plants in a state of putrefaction; while, when closer to the nostrils, it seems to have a smell between that of sulphur which is burning and oxy-muriatic acid. This vapour is condensed with difficulty; it acidulates water if passed through it: upon analysis, I discovered plenty of muriatic acid, and some atoms of sulphuric acid. I have often repeated this experiment by passing the acid into a receiver with two orifices, the moistened sides of which were covered with sulphur. I received the produce into a second recipient of a large size, to the neck of which was adapted a crooked tube, which I plunged into water.

2d, The oxy-muriatic acid which is passed through water in which sublimed sulphur has

been diluted, produces no change in the sulphur.

3. The oxy-muriatic acid precipitates in yellow the sulphur of the liquid sulphuret of alkali.

The oxygen engaged in the oxydes of some metals, may facilitate the combustion of sulphur, without converting it into sulphuric acid, at least in proportion to the oxygen it contains.

As among all the metallic oxydes, that of manganese is that which may be employed with most economy, at the same time that it is one of those which yields its oxygen with most facility, I thought proper to try its action upon sulphur.

1st, Equal parts of sulphur and oxyde of manganese, distilled in a retort, to which I had adapted a receiver, the sides of which were moistened with water, afforded plenty of white sulphurous vapours, a part of which was condensed in the receiver, and supplied me with 3 ounces of acid at 22 degrees, out of 3 pounds of mixture. This concentrated acid only left some grains of true sulphuric acid; what remained in the retort was white, friable, and dirty, and furnished me with sulphuret and sulphat of manganese, mixed with native sulphur.

Green obtained nearly similar results from a similar experiment.

2d, Oxyde of manganese mixed with sulphur in a furnace with leaden chambers, facilitates the combustion; but in order that the effect may be perceptible, the proportion of manganese must be at least half that of the sulphur. It appeared to me, that the most convenient form which could be given to this mixture, in order to produce the combustion of it, would be that of balls, made by moistening the two substances with enough of water to form a paste. These balls should only be employed when they are dry: but although manganese is discoloured, and loses its oxygen by combustion, almost no sulphurous acid is obtained.

It may be concluded, from the numerous trials I made to make use of the metallic oxides, by burning them along with sulphur in the fabrication of sulphuric acid, that none of them can be advantageously employed for this purpose; and that although they may hasten combustion, they do not conduce to the formation of sulphuric acid.

Some facts being known respecting water, and the nature of its constituent principles, deter-

mined me to try the effect of this liquid in the combustion of sulphur; and I made the following experiments on the subject:

1st, I kneaded sulphur with water, and burned the paste in furnaces with a leaden chamber: the flame is whiter and longer than that of sulphur by itself; the condensation of the vapours is easier, and the produce more considerable in volume; the water is weakly acidulated; but I do not think this intermedium can be employed with advantage, considering that what is produced by the concentration of acidulated water is almost nothing.

2d, I melted sulphur in vessels with very strait necks, in order to avoid the inflammation: I poured water upon the surface of the liquid, and hot sulphur, sometimes in drops and sometimes in vapours; and I saw that from the moment the water was applied to the surface of the sulphur in fusion, there took place a disengagement of a white and thick vapour, which, when collected and condensed in receivers, only presented me with water almost insipid, and sublimed sulphur.

3d, If we throw some water, drop by drop, upon a mass of inflamed sulphur, the flame

increases and becomes white; the produce of the combustion, however, yields no more concentrated acid than if we had burned sulphur without any mixture.

I once thought, that by employing pure oxygen gas in the combustion of sulphur, sulphuric acid would have been produced, without the assistance of any other substance; but I was easily undeceived by making an experiment; and whether I burned the sulphur in the gas, or directed the current upon a surface of sulphur in combustion, the result was constantly the same, *i. e.* combustion may be accelerated by this method, but sulphuric acid cannot be formed in any sensible quantity.

From all the experiments I made, in order to effect the combustion of sulphur, it may be concluded:

1st, That the very variable proportions of the oxygen gas which may be employed in the combustion of a determinate portion of sulphur, may more or less accelerate the combustion, without always sensibly augmenting the production of sulphuric acid.

2d, That the bodies which have oxygen for their base, and which give it up at a moderate

heat, as some metallic oxydes do, assist combustion more or less, without producing sulphuric acid.

3. That the substances which, when placed in contact with sulphur in combustion, give up to it their oxygen, and by producing a violent heat, are the only ones which can convert sulphur into sulphuric acid.

According to these principles, we may place at the head of those substances which we may mix with sulphur, the nitrate and the oxygenated muriate of potash.

And we may already conclude, from the above results, either that the combination of sulphur with oxygen requires a very high temperature in order to form sulphuric acid, or that the sulphuric acid admits of a very large dose of caloric, as a principle necessary to its constitution.

I do not doubt that we shall succeed in forming sulphuric acid by employing a smaller dose of nitrate of potash when we operate the combustion of the mixture over bodies, or in furnaces or tubes strongly heated. In this case, the heat of the fire will advantageously concur with that produced by the decomposi-

tion of the saltpetre in effecting the combination of the oxygen with the sulphur, and thus composing sulphuric acid.

The nitrate is preferable to the oxygenated muriates of potash, because it is more common, and because its decomposition mixes few foreign principles with the sulphuric acid, which is the produce of combustion.

But, nevertheless, some choice must be made among the nitrates known in commerce; because they are generally more or less mixed with foreign substances. When we employ common saltpetre, for instance, there is a great part of it which does not serve for combustion, and consequently is of no use in the formation of sulphuric acid.

We cannot even regard the substances which are foreign to the nitrate as indifferent in the composition of the mixture; for if that was the case, it would be sufficient to keep an account of them, in order to employ the real nitrate in convenient proportions. It is sufficient to know, that these foreign substances are muriates, which in their decomposition absorb a portion of sulphuric acid, while the muriatic acid raises itself in vapours, in order

to mix with the water of the chambers. There is, therefore, an advantage in employing the purified nitrate.

I have seen the nitrate mixed with the sulphur in various proportions in different manufactories; it is employed from one-fifth to one-tenth of the weight of the sulphur. The dose, however, is not a matter of indifference: the stronger the proportion of the saltpetre is, the greater is the heat; the vapour is more easily condensed; and the smell of the acid which is disengaged, is less pungent: but when the proportion of saltpetre is too strong, besides the extreme heat which is produced, volatilizing a portion of the native sulphur, and the more considerable residue retaining, at a great loss, a greater quantity of the acid produced, the sulphuric acid obtained is considerably heightened in price, by the proportion of saltpetre exceeding what is requisite. Besides all this, when the proportion of saltpetre is not sufficient, almost all the sulphur is elevated in the state of sulphurous acid.

There is a medium, therefore, where we ought to stop; there are exact proportions which it is necessary to be acquainted with;

and I am convinced that the most convenient proportion is between a seventh and eighth of saltpetre to the weight of sulphur employed.

When the practice was abandoned of distilling sulphates to extract the acid from them, the mixture of sulphur and saltpetre was burned in enormous glass globes, in which a layer of water was placed, in order to condense and dissolve the vapours; and the aperture was carefully closed the instant the mixture became inflamed, to prevent the loss of any part of the vapours.

This process was succeeded by another, which consisted in operating the combustion in chambers lined with lead. These latter establishments, although more expensive in their construction, are nevertheless preferable, because they admit of operating on a larger scale, and when once constructed, they occasion less expence for keeping them in repair.

These leaden chambers, are generally in the form of an oblong square, covered with a double shelving roof. The size varies according to the object in view with the manufacturer, and often according to the room which he wishes them to occupy. In general, those chambers which are about twenty feet broad

by twenty-five long and fifteen high, seem to me to be of the most advantageous proportions.

As these chambers are liable to suffer the vapours or liquid they contain to run out, they should be isolated so as to admit of their being inspected on all sides, above and below, and consequently they should be constructed in the middle of a large enclosure, upon stone corners, at five or six feet from the ground, and from the walls and the roof of the enclosure: all the solderings should be perfectly visible, in order to repair them the more easily, and the workmanship should always be so solid, that the constant weight of the leaden plates may not cause it to give way. The leaden plates are fixed upon the interior surface of the wood-work by soldering clasps of the same metal to it, which are fastened to the uprights of the wood-work by means of iron nails.

As lead is very expensive, attempts have been often made to find a substitute for it, in some substance which should be inattacking by the acid, and which should resist the heat produced by the combustion of the mixture.

Plates of glass, varnished bricks, and vitrifiable stones, have been successively suggested.

Combustion apparatus have been constructed with these materials; but the use of lead has been constantly reverted to, because in these different articles neither the solidity, the durability, nor the facility of execution, which large plates of lead afford, was to be found.

I have myself carefully constructed a chamber, 80 feet long, and 40 broad, by 50 feet high. I lined the walls of it with a coat of plaister, over which I applied several coats of a boiling mixture formed of equal parts of turpentine, resin, and yellow wax. I operated in this chamber for eighteen months without interruption; but the roof of this enormous edifice having suddenly fallen in, I had not courage enough to rebuild an apparatus which had cost me six months hard labour, and which had considerably injured my health.

The manner of burning the mixture of saltpetre and sulphur, varies also in the different manufactures: in some the mixture is lighted before putting it into the inside vessels, into which it is introduced as soon as it is inflamed, with the help of a carriage which supports the vessels in which it had been deposited. In others, it is burned even in the interior of the chambers, upon the floor of which

a place is reserved to construct the fire. I made use of this practice at first, but I finished by constructing furnaces outside of the chambers, from which I transmit the vapour into the interior, by means of vents, which terminate the furnaces.

The two first methods differ a little from each other: the first of all however is the most troublesome; the guiding and support of a carriage is very expensive, as the iron and wood of it are most easily deteriorated.

The second method is more simple, and I practised it a long time before having recourse to the third one, which deserves the preference to all the rest.

Great attention should be paid however to the construction of the furnace, for not only is it more easily disarranged, but it produces very different effects, accordingly as it draws more or less. I proved that we may obtain, at pleasure, from the same mixture, either sublimed sulphur, liquid sulphur, sulphurous acid; or sulphuric acid, according to the draught of the furnace.

In order to facilitate the condensation of the vapours, it has been usual to put a layer of wa-

ter upon the floor of the chambers ; but in some manufactories they content themselves with moistening the walls of them from time to time by means of a pump.

In proportion as the combustion is active, the dilated vapours endeavour to escape by every chink which presents itself ; but when they condense, the external air penetrates into the chamber, and it is even advantageous to contrive some small apertures which may be conveniently uncovered in order to facilitate the entrance of it.

As soon as the vapours are sufficiently condensed, if the door is opened a very penetrating gas is seen to escape, which is only sulphurous acid mixed with some parts of nitrous gas, and they become red by the contact of the external air.

When the vapour which issues from the door when opened is white, it is a certain sign that the condensation is not complete. It is therefore prudent to shut the door again ; because, besides the issue of the vapours being a loss, they might injure the neighbouring inhabitants, and burn the plants in the fields around.

The produce of the combustion is of two

kinds: 1. the acid which forms a layer upon the floor of the chamber; 2. the residue of the fire.

The liquid acid is not taken up until it marks 40 or 50 in Baumé's areometer. If it is drawn off sooner, the concentration of it is not only more tedious and more expensive, but the concentrated acid is not of so good a quality, in consequence of the sulphates collected and left dissolved in the acid.

What remains in the fire when the combustion is well done, is only white crusts, almost entirely formed of sulphate of potash. When the combustion has been ill conducted, the crusts are brownish; plenty of native sulphur is also distinguished among them, and they are put into the fire to burn them completely by the help of a new mixture.

The acid proceeding from the chambers, or, to speak the language of the workmen, *the water of the chambers*, cannot be applied to every purpose, since it does not dissolve indigo, and does not decompose the nitrates and muriates without the assistance of heat; but in this first state, it may be employed in dissolving iron

and zinc for making sulphates, to take the grease out of, or to ley such cloths as are destined for printing, and in a word, for every purpose in which oil of vitriol is employed, when by means of water it is reduced below the 45th degree of Baumé's areômeter.

In order to effect the concentration of the sulphuric acid, glass retorts are generally employed, which are managed in the sand-bath; but I have adopted a method which always appeared to me to be speedy and more economical: I first carry the water of the chambers into leaden kettles, where I concentrate it to the 60th degree; and I finish the concentration in stone retorts, which I expose to the naked fire upon galleries.

In order that the acid may be at a proper degree of concentration, it should mark 66 degrees, and it should be clear like water. When it is not concentrated to this point, it contains some atoms of nitric acid, which give a green colour to the solution of indigo, and consequently do not admit of its being employed for this purpose.

When all the operations are carefully gone

through, we obtain of concentrated acid, at least double the weight of the sulphur employed.

They continue to manufacture, in some parts of Germany, an oil of vitriol by the distillation of the sulphate of iron : for this purpose, as we have already observed, they begin by calcining to a red colour the sulphate, and they afterwards distil it in stone retorts ; there passes over—1st, a little sulphurous gas ; 2d, oxygen gas ; 3d, a thick liquor, which coagulates in the receiver. The liquor of the receiver is an icy acid, which resolves into steam as soon as it comes into contact with the air ; and the vapours of which, in condensing, form white transparent crystals, figured into square tablets. It should be observed, that the sulphate, when ill calcined, and when containing the remains of the water of crystallization, does not furnish any acid, although heated in the same fire ; which proves, that by calcination we oxydate the sulphat, change its composition, and give new properties to the acid ; and that when we afterwards proceed to distil it, a part of the oxygen, fixed by calcination, remains united to the acid, while the other

escapes in the state of gas. The distillation of the sulphuric acid over manganese, also furnishes a smoking acid, but less than that of the sulphate.

This smoking acid is known by the name of *icy acid*, *smoking acid of Nordhausen*, or of *Saxony*.

It seems, therefore, that sulphur, in passing to the state of an acid, is susceptible of three degrees of oxydation : 1st, sulphurous acid ; 2d, sulphuric acid ; and 3d, smoking acid.

Sulphuric acid is very susceptible of freezing and crystallizing, at a temperature some degrees below zero ; but in this state, it has no relation with the smoking icy acid.

When we dilute the smoking acid in water, it loses this quality, and cannot acquire it again.

This smoking acid is preferred by artists, particularly by dyers, to that which proceeds from the combustion of sulphur : it is even a great deal higher priced than the latter.

We shall have occasion to speak of the use of the sulphuric acid in treating of dyeing, and other operations where it is employed as an intermedium, or as an agent.

SECTION III.

Of the nitric acid.

Nitric acid exhales a strong and disagreeable smell.

It imprints a yellow and solid colour upon the skin, and upon white silk.

It destroys completely the blue in mallows and violets.

That which is known in commerce, marks from 30 to 45 degrees.

It is generally of a yellow colour, often it is white, and sometimes of an orange red; when it is concentrated, it emits vapours, which become red on contact with the air.

It is easily decomposed by all the combustible bodies, and produces in this process, plenty of red vapours.

The nitric acid is known in commerce by the name of *aqua-fortis*, *spirit of nitre*, and *second water*; according to its degree of concentration.

The nitric acid has never been found in a free state: it is formed every day by a course of circumstances, which we shall sub-

sequently explain ; but it enters into combination with the ambient bodies from the instant it is formed ; and it is from these combinations we extract it, in order to apply it to the purposes of commerce, for which the earthy and alkaline nitrates are generally employed.

The substances constantly made use of to decompose the nitrates are—the sulphuric acid, the sulphate of iron, and the argillaceous earths, and boles, more or less charged with ochre or oxyde of iron.

When sulphuric acid is used, the nitrate is put into a retort in the state of powder ; half its weight of sulphuric acid is poured over it ; a receiver is adapted to the retort, and the operation is facilitated by means of fire. The distillation takes place in the sand-bath or in the naked fire : in the former case, unluted glass retorts are made use of ; in the latter, stone or luted glass retorts are used.

When we operate with the sulphuric acid used in commerce, without diluting it, the nitric acid passes in vapours almost dry, and there results an acid very much condensed ; the apparatus is considerably heated, so that

the condensation would be prejudicial, if wet cloths were not kept under the receiver, or if it was not kept one-third under water. By employing the acid weakened with water, or as it is extracted from the leaden chambers, the operation is more tranquil, but the acid is also weaker, and the distillation slower and more tedious.

In all the manufactories where the aqua-fortis used in commerce is manufactured, it is usual to decompose the nitrates by means of argils, or solar earths.

The choice of these earths requires a great deal of attention on the part of the distiller of aqua-fortis. The red and very friable earths, mixed with small grains of iron ore, are the best. They should not be too dry, however, for in that case they decompose imperfectly, and it requires an extremely brisk and well kept up heat to finish the operation. The red earths, the surface of which is shining and almost greasy, should be preferred. There are some gray argillaceous earths, intersected by red veins, which, although inferior to those we have now mentioned, are, nevertheless, advantageously em-

ployed : those made use of at Paris are of this kind.

In general, an earth which may be used in the distillation of saltpetres, should contain an oxyde of iron, susceptible of undergoing a stronger oxydation by fire : this explains why the earths employed are redder after the operation.

The retorts used in the distillation, are of stone or glass : at Paris, they are all of stone, and the retorts, or *cuines*, as they are called, employed there, are very small ; while in the south of France, they are of a green glass, called *verre chambourin*, and the retorts are so large, that they receive 75 or 80 pounds of mixture, and yield 20 or 30 pounds of any acid.

The furnaces, which we called *galleys*, only vary in proportion to the size of the retorts, and the nature of the combustible. In general they are formed of two parallel walls, between which iron or earthen arches are placed, in order to support the retorts.

The retorts, particularly those of glass, should be very carefully luted : for this pur-

pose, some clay should be put into a trough, after having previously divided it and bruised it; it is then moistened with water, and when it forms a soft ductile paste without lumps, it is taken from the trough and mixed with fresh horse-dung: the mixture is then carefully kneaded until the dung and the clay appear to the eye as if one and the same body. This luting is applied with the hand, taking care to make it adhere well to the surface of the glass, and to form a coating of an equal thickness over all the surface, and to leave no chink whatever. The luting is dried in the sun, or by a stove, according to the season of the year, or the climate.

Saltpetre is the salt generally employed in the distillation of aqua-fortis; but as its different states yield very different qualities of acid, it is indispensably necessary to be acquainted with the different qualities of saltpetre employed in manufactories, in order to calculate those of the acids which they produce.

Saltpetre, as it comes from the saltpetre works, is known by the name of *crude salt-petre*; it contains, beside the nitrate of potash,

nitrate of lime and magnesia, and earthy and alkaline muriates.

When, by a series of processes which we shall describe under the article nitrates, the nitrate of potash has been freed from all these foreign salts, the saltpetre then acquires the name of *refined saltpetre*.

Independently of these two states of saltpetre, there is also sold to the distillers of aqua-fortis a thickened mother-water, which is called *recuit* in the south of France; and a saltpetre in grains, which is called *salpêtre gros*.

These two last substances, *recuit* and *salpêtre gros*, require from us some details as to their preparation, in order that we may explain the nature, and foretel the quality of the aqua-fortis which they ought to furnish.

The ley of nitrous earths contains, besides the nitrate of potash, the proportion of which varies very much, a good deal of earthy or alkaline salts, which crystallize less easily; in such a manner, that if, after having drawn off a first proportion of crystals from nitrate of potash, the residue is concentrated until it is

of the consistence of a paste, or extract, we obtain a clotted mass, which is called coarse saltpetre (*salpêtre gros*).

When, after having collected, by several successive evaporations and crystallizations, all the nitrate which can be extracted from ley, the mother-water is thickened to 45 degrees; it is then called *recuit*, and sold to the distillers to draw off the acid from it.

These two last preparations are made in the county of *Venaissin* (now in the department of *Vaucluse*), where, before its union with France, almost all the aqua-fortis employed in the numerous manufactories of the south was made. At present, since the French regulations concerning the manufacture and sale of saltpetre are in full force, the manufacturers are obliged to deliver to government all the produce of their manufactories; and as they only receive nitrate of potash, the manufactories cannot continue to make thick saltpetre and *recuit*. But we are forced to admit, that the distillation of aqua-fortis has suffered much on that account; because it is ascertained, that their thick saltpetre and their *recuit*, furnished, with facility and econo-

my, aqua-fortis of the best quality that could be wished for dyers; and we must also admit, that it cannot be made at the same price, nor obtained constantly of the same quality, by employing the saltpetre of the powder magazines of government.

The nature of the acid, and the process of distillation, vary, according to the state in which the saltpetre is employed: if pure saltpetre is made use of, we may determine the proportions between the salt and the bolar earth, in consequence of the results presented by the following experiments:

Two hundred pounds of pure saltpetre and 200 pounds of bolar earth, carefully mixed and distilled, yielded a little nitrous gas, some carbonic acid, and 75 pounds of pure acid, at 40 degrees, and very white. The residue presented plenty of saltpetre not decomposed.

It results from this first experiment, that the proportion of the bole, when employed in equal parts, is not sufficient, for the heat was carried so high as to melt the glass. It results, also, from this, that the acid is not what is called by the workmen, red acid, except when the bole is employed in a stronger proportion.

One hundred and fifty pounds of pure saltpetre and 300 pounds of bolar earth, distilled with the same care, yielded a little less of carbonic acid, a little more nitrous gas, and 126 pounds 8 ounces of acid, at 39 degrees.

One hundred and fifty pounds of saltpetre and 400 pounds of bolar earth, furnished plenty of vapours, and without interruption, until the end of the operation, and 131 pounds of acid, at 41 degrees.

One hundred pounds of saltpetre and 300 pounds of bolar earth, furnished 87 pounds of yellowish acid, at 39 degrees.

We may conclude from these experiments, that when we make use of a red bolar earth, dry and pure, the fracture of which is unctuous, like that which certain *slimy* ores of iron present, we should employ the earth in the proportion of two or three parts to one of saltpetre.

These are the most convenient proportions for pure saltpetre; but they should vary according to the quality of the salt employed. When, for example, we distill common saltpetre, the quantity of the saltpetre is only in the proportion of four or five to one; and the

rest contains muriate of soda, which it is difficult to decompose ; so that, in this case, two parts of earth against one of saltpetre, form a convenient proportion, in order to decompose all the nitrate.

When we operate upon thick saltpetre, the proportion of it may be augmented a tenth, and even an eighth, if it is not well dried.

And if *recuit* be used, marking 45 degrees, this syrupy liquor is kneaded with earth, and a dry paste is formed of it, which is put into the retorts ; the mixture is generally formed of 30 parts of *recuit* to 20 of earth.

But, as the *recuit* employed at 45 degrees of concentration, occupies a considerable space, I thought it most advantageous to thicken it in a large kettle, by means of evaporation, and to distil it then like coarse saltpetre.

At Paris they employ, in the distillation of aqua-fortis, a fat, unctuous, grayish earth, intersected with some reddish veins, which is brought from the environs of Vanvres. It is dried in furnaces, by placing it in them as soon as the coals have been withdrawn from them. It is then pounded, and passed through a twig sieve. A mixture is afterwards made of about

180 pounds of this earth with 80 pounds of bruised saltpetre, and the kettles are filled with it, which are arranged upon a galley furnace to the number of 32 or 36, and in two rows: the mixture is sometimes wetted, when it is wanted to obtain a weak acid at 22 or 25 degrees.

Chemical observation, according to which it is evident that the muriates of lime are almost indecomposable by the solar earths, while those of magnesia are easily decomposed, has led us to mix lime with the mixture of saltpetre and earth, in order to precipitate the magnesia from them, and convert all the earthy nitrates into nitrates of lime. This process, for which we are indebted to M. Berard, my pupil, and associate with me in the manufactories of chemical products I established at Montpellier, is now adopted in several establishments. By this method, we obtain by distillation only pure nitric acid, which may be extracted from all kinds of saltpetre, and which presents a very great advantage to distillers. We may, therefore, with the same common saltpetre, make at pleasure nitric acid for the use of hat-ters and jewellers, or nitro-muriatic acid for the use of dyers.

The receivers are very soon filled with red vapours * ; these are dissolved in the acid, which condenses itself, and they give it a greenish colour.

In proportion as the heat increases, the receiver becomes heated ; the red vapours fill the capacity of it so completely, that we cannot see through it any longer ; streaks of acid only are seen, which flow down the interior, and the operation goes on in this manner until it is finished.

When it is perceived that some retorts work less, more combustibles are applied to them, and a considerable draught of air is established around them, by making two small apertures at the origin of the neck of the retorts. These vents are closed when the operation has resumed its full activity.

It is known that the operation is at an end : 1st, when the receiver becomes cool ; 2d, when the vapours which occupy its whole capacity are condensed, and when the interior

* I am here supposing that glass receivers are employed, by means of which we may more easily know what passes during the operation.

is clear ; 3d, when, upon looking at the inside of the retort through the receiver, it is distinctly perceived by the redness it has contracted.

The workman who directs the operation, draws the fire from the grating, and leaves the door of the fire-place open in order to hasten the cooling.

When the apparatus is cold enough to be dismounted, the luting is cut which joins the retort to the receiver ; and the latter is taken off to pour its contents into proper vessels. The funnels made use of in the manufactories in the south, in order to pour out the acids without loss or danger, have their upper edges folded inwards, so as to form a reversed water-conduit. By this form, the acid which, when poured upon the sides, sometimes rises and escapes by the edges of the common funnel, cannot run this risk. It is thrown back into the inside, as soon as it arrives at the conduit we have been describing.

We may reduce all the products of distillation to two kinds : the residue of the retort, and the acid which has come over into the receiver.

The residue of the retort is of three kinds, according to the process employed to decompose the saltpetre.

When sulphuric acid has been made use of as an intermedium, the residue is a sulphate of potash, which hitherto has been of very little use in the arts; but of which a great quantity is now beginning to be used, as well for the purpose of combining it with the sulphate of alumine, and forming alum, as to decompose the mother-waters of the saltpetre manufacturers.

When solar earths have been resorted to, in order to decompose saltpetre, the residue of the distillation only presents an earth strongly calcined, mixed with a little muriat, which has escaped decomposition, and some alkaline base of the nitrate, which forms with the earth such an intimate combination, that it cannot be separated from it by leying. This earth, known by the name of *earth of aqua-fortis*, or *earth of the distillers of aqua-fortis*, may be applied to the same purposes as puzzolani, and form with lime a valuable cement for buildings under water, for coating to basons, tubs, &c.

It is more than 20 years since I published

the method of manufacturing aqua-fortis and alum at one and the same time : for this purpose I take a clay, rich in alumine and exempt from iron ; I dry it and bruise it properly. I then mix it with equal parts of saltpetre and sulphuric acid, marking 40 degrees : the distillation is conducted as usual ; the nitric acid passes into the receiver, and the residue only requires to be lixiviated and crystallized, to form an alum of the first quality.

The acid obtained by the distillation of saltpetre has different qualities, according to the purity of the saltpetre employed.

Pure saltpetre furnishes a pure acid, which may be used to dissolve the mercury for forming what is called the *secret* by hatters, and which may be similarly employed in the delicate operation of the solution of metals : it is on account of these two uses that it is called *aqua-fortis for the hatters*, and *aqua-fortis for dissolving the metals*.

The common saltpetres, the mother-waters, and the thick saltpetres, furnish nitro-muriatic acid, which essentially constitutes the *aqua-fortis* of commerce. It is particularly

used for dissolving tin, and forming what the dyers call the *composition for scarlet*.

It is very rare if aqua-fortis does not contain more or less muriatic acid, which it is necessary to ascertain and deprive it of, to be able to employ it in certain operations, particularly in the solution of gold with silver. The method most practised for separating the muriatic acid, consists in pouring the solution of nitrate of silver upon the acid, which becomes pale, and then white, if it contains any muriatic acid; the liquor is allowed to clear, and solution of silver is added, until no more precipitate is formed. The liquor is then decanted from off the deposit, which is only an insoluble muriate of silver; and the acid thus purified, bears the name of *precipitated aqua-fortis*. By distilling the acid which floats above the deposit, we have the advantage of obtaining it still purer, because we clear it from the little sulphuric acid it may contain, which forms a salt, soluble with silver. It is of use, however, to know, that sulphuric acid is less dangerous than muriatic acid, and that it may exist without any bad consequence

in the nitric acid, provided always that it is in a small quantity.

There are some distillers who precipitate their aqua-fortis by the acetite of lead, which seems to have the advantage over the nitrate of silver, of forming insoluble salts equally with the muriatic acid and with the sulphuric acid; but M. Berthollet has demonstrated, that the muriate of lead was soluble by the nitric acid, so that it partly remains in the acid; and in this case, there even passes over in the distillation a little muriatic acid, as observed by M. Prieur.

The pure aqua-fortis employed in the mints, marks from 36 to 45 degrees, while that prepared for the hatters, only bears from 32 to 36.

The aqua-fortis intended for dyeing ought to contain a little muriatic acid; and it is on account of this mixture of the two acids, that it has been called nitro-muriatic acid: when the muriatic acid is not in a strong enough proportion, the aqua-fortis only corrodes the tin, and the dyers reject it, saying that it *precipitates*. When aqua-fortis contains too much muriatic acid, the composition only drenches the scar-

let in place of clearing or brightening it up. There must therefore be exact proportions between the two acids; and the thick saltpetre from Avignon is the substance which has hitherto appeared to me to present the most advantages in this branch of manufacture.

What renders the operation of the preparation of aqua-fortis for dyeing very difficult and hazardous in appearance, arises on the one hand, from the great variety of saltpetres; on the other, from the great difference of opinion which exists among dyers in the employment of this acid. In France, the aqua-fortis is weakened with water before using it; in Spain, on the contrary, it is employed at its full strength. The dyers of the former country generally complain of the weakness of their acid; those of the latter always find it strong enough, and it is furnished to them at four and six degrees under that of France. In the same country, often in the same town, a dyer is in the habit of dissolving marine salt or sal ammonia in aqua-fortis, while his neighbour employs it without any mixture: it is evident, that the same aqua-fortis will be judged of differently in the two workshops.

Such are the varieties of detail which disconcert a distiller who is a novice in his art ; and it is the knowledge of all tastes, all the practices, and all the processes—a knowledge only to be acquired after long experience—which gives the experienced manufacturers a great advantage over the new ones.

The aqua-fortis used in dyeing, generally marks from 30 to 35 degrees. At Paris, it is packed in stone bottles ; in the south, it is in *cavettes*, as they are called, of green glass, which contain from 20 to 25 pounds of it, and 10 of these form a case.

We are indebted to Lavoisier for the first step which has been made in the analysis of the nitric acid. It was in 1776 that this celebrated chemist succeeded in reducing this acid into two very distinct principles : one pound of nitric acid, distilled over mercury in the hydro-pneumatic apparatus, furnished him with one ounce seven drachms two grains and one half of oxygen gas ; one ounce 51 grains and one quarter of nitrous gas ; and thirteen ounces eighteen grains of water.

After the operation, the mercury was of the same weight and the same form as before. The

combination of these three products in the same proportions, reproduced the same quantity of acid as that which had been made use of in the experiment.

A similar decomposition of the nitric acid takes place in every case where a direct action is exercised upon the metallic substances, and upon vegetable and animal matters; but, in the two last cases, the oxygen is combined with the carbon or the hydrogen, and forms carbonic acid and water; so that we do not obtain it pure, as when we operate upon the metals. The red vapour which is liberated when the operation is performed in the open air, is this same gas, which, when collected through water, and deprived of the contact of the atmospheric acid, is invisible.

But it still remained to us to know the nature of this nitrous gas, and we are indebted to Mr. Cavendish for a fine experiment, by which he has proved that this gas is not a simple body, but a compound of oxygen and azot: he introduced into glass vessels, seven parts of oxygen gas, obtained without employing nitric acid, and three parts of azotic gas: he passed the electrical spark through this mixture, which

gradually diminished in volume, and resolved itself into nitric acid.

Messrs. Van Marum and Lavoisier have since repeated this experiment, and confirmed its results.

Other chemists, by following another course, have attained the same results also : Mr. Milner, of the Royal Society of London, has made nitrous gas by passing ammoniacal gas through the oxyde of manganese, reddened in a gun-barrel.

As the nitrous gas has some constant characters and uses which are proper to it, we shall now examine those properties :

Mr. Kirwan has estimated the specific gravity of the nitrous gas at 54, that of oxygen being 50. Mr. Davy has estimated it at 50, that of oxygen gas being 51 : whence M. Berthollet has concluded with justice, that these two gases experience only a feeble combination, and that consequently the decomposition of the nitrous gas ought not to meet with great obstacles.

Messrs. Priestley and Cavendish observed, that this nitrous gas is dissolved in water. This phenomenon appeared at first to be only

owing to the conversion of a portion of this gas into the state of nitric acid, by its combination with the oxygen gas which the water holds in solution, because the water thereby becomes slightly acid ; but Mr. Davy has proved, that 100 parts of pure and boiled water could absorb 11,8 of nitrous gas, without acquiring any taste, or reddening the blue vegetable colours : this leads us to think, that water by itself exercises a dissolving virtue upon this gas, which is necessarily increased by the portion of the gas which may combine with the oxygen, which is almost inseparable from the water, and an acid is then formed.

The nitrous gas is easily and abundantly dissolved in the nitric acid ; and it is to the proportions in which it is found, that we ought to refer the variety of colours which this acid presents. We have already observed, that in the progress of the distillation of aqua-fortis, the colour of the acid is seen to change by the absorption of the nitrous gas, which is liberated at every moment of the operation : at first the feebly-acid water of the receiver is white ; gradually it becomes of a green colour ; from green it passes to yellow, and from yellow to red : in

this last state, the nitrous gas is in excess ; it endeavours to escape, and produces by the contact of the air and its combination with oxygen, a red, acid, suffocating vapour, very soluble in water.

The nitrous acid dissolves so much the more nitrous gas, the less water it contains. It is on this account that, when the nitrous gas escapes during the distillation, and begins to redden the receivers, care is taken to remove the phlegm which has already passed, in order to facilitate the solution of the gas.

Nitric acid, which holds gas in solution, easily absorbs oxygen ; and gradually all the nitrous gas passes to the state of nitric acid ; which increases the specific gravity of the acid, and adds to its virtues in every use to which it is applied.

Heat, the alkalis, and water, drive off the nitrous gas from its solution in the acid. The metals, the vegetable and animal substances upon which we employ the action of the nitric acid, develop a new quantity of it, by the decomposition of a portion of the acid, and the fixation of a part of its oxygen upon these bases.

The solution of the sulphate of iron, absorbs the nitrous gas, loses its transparency, and assumes a blackish colour. This property has become very useful for separating the nitrous gas from the other gaseous substances. M. Humboldt has made a false application of it, in supposing that the nitrous gas was always mixed with a portion of this azotic gas, from which he thought of clearing it by this method. M. Berthollet has shewn that this azotic gas was only there accidentally, and that the absorption of the nitrous gas itself, which was constant, had imposed upon this celebrated naturalist.

Hitherto, the substance which has best succeeded in decomposing the nitrous gas, has been iron. The Dutch chemists observed, that this gas, when made to continue over iron, even without the assistance of heat, passed to the state of *oxyde of azot*, and ended by reducing itself into pure azot. We have already said, that Mr. Milner, by passing the nitrous gas through a gun-barrel made red hot, had obtained oxyde of azot and pure azot, and that the oxyde which is made to repass through the filings, converted itself entirely into azot.

Mr. Van Marum, on decomposing, by the electrical spark, the nitrous gas over iron, had for a residue, in pure azot, 0,46 of the primitive volume; but there was formed a yellow powder, which contained a small quantity of acid; this varied the proportions a little.

M. Berthollet, on decomposing the nitrous gas by a mixture of iron-filings, sulphur, and a small quantity of water, obtained 0,44 of residue. He observes, that a little ammonia must have been formed, which diminished the residue.

Mr. Davy concluded, from all the facts established by the decomposition of nitrous gas, that its principles are in the following proportions: 44 parts in weight of azot, and 56 of oxygen.

Where, in the cases we are about to mention, the nitrous gas does not undergo a complete decomposition, that particular gas is formed which the Dutch chemists have called *gaseous oxyde of azot*, or *oxyde gas of azot*, which Priestley had described under the denomination of *dephlogisticated nitrous gas*, and which Mr. Davy, to whom we are indebted for

an important work upon this subject, has named *nitrous oxyde*.

All substances which can take the oxygen from nitrous gas, are proper for producing the oxyde gas of azot.

What eminently distinguishes this gas, is the property which it has of giving to combustion the same vivacity that oxygen gas does, with this sole difference, that its effect is not very sensible, except upon bodies which are well inflamed; which happens, no doubt, because there must be either a strong affinity or a lively heat, in order to decompose this gas, and extract the oxygen, in order to apply it to combustion. It is for the same reason that it cannot be breathed by a bird, where the function of breathing cannot be interrupted or altered without danger, while it supports the respiration of a human being.

This gas is dissolved in water, as Priestley observed; it is liberated from it by ebullition, without any alteration; it undergoes no change when it is mixed with oxygen or nitrous gases.

When the metals decompose the nitric acid,

there is produced nitrous gas, and gaseous oxyde of azot, or a mixture of both, according to the energy of the acid.

The Dutch chemists lay it down as a principle, that the metals which decompose the nitric acid, form nitrous gas when the acid is concentrated, and gaseous oxyde of azot when the acid is very much diluted by water. But it would seem that the production of the nitrous gas depends in a particular manner upon the energy with which the acid is decomposed upon the metal, and that we may obtain at pleasure the one or other of these gases, by moderating or accelerating the action of the acid.

The decomposition and the formation of the nitric acid has made us acquainted, to the most scrupulous exactitude, with the proportions of the principles which constitute it in its different states.

It results from the experiments of Mr. Cavendish, as to the formation of the acid; that the proportion of oxygen is to that of azot as 253 to 100; but if we take the weight of the gases in place of their volume, the pro-

portion is as 25 of azot to 75 of oxygen, while that of the nitrous gas is 44 of azot to 56 of oxygen.

SECTION IV.

Of the phosphoric acid.

Nature presents us with the phosphoric acid combined with metals, earths, or alkalis; but she no where presents any of it in the state of a free acid, except in urine, according to the observation of M. Berthollet.

It is by the combustion or oxydation of phosphorus that this acid is obtained.

This combustion may be managed in different ways.

Lavoisier, in 1777, proposed to burn phosphorus by means of the burning lens, under a bell-glass inverted over mercury: there is then formed a great quantity of white flakes, which attach themselves every where to the sides of the bell-glass: this is concrete phosphoric acid, which resolves into a liquid the instant it comes in contact with a humid atmosphere, and forms an unctuous and inodorous liquid.

The same chemist recommends, that the sides of the bell-glass in which the combustion is effected, should be moistened, in order to dissolve and fix the acid vapours as they are disengaged.

In all cases where the combustion of phosphorus is rapid, and takes place with deflagration, a part of the phosphorus escapes combustion, and is dissolved in the acid which is formed. This is the reason why slow combustion has been always resorted to for the preparation of phosphoric acid.

In order to form an exact idea of the combustion of phosphorus, it ought to be known, that at the temperature of the atmosphere, the phosphorus is partly dissolved in azot, and there continues in a gaseous state, and in a state of extreme division; so that it thereby becomes more acceptable to the action of the oxygen, which burns it. By this first combustion, the heat increases, and the rest of the phosphorus is inflamed; so that the combustion of phosphorus takes place more easily, and at a lower temperature, in air mixed with azotic gas, than in pure oxygen gas. The azotic gas, charged with phosphorus, is in-

creased in its primitive volume by one-fortieth, and becomes luminous.

The combustion of phosphorus at a low temperature, is therefore effected by the intermedium of azot ; but when the temperature is raised to 30 degrees, there is then a direct deflagration and combustion, by means of oxygen.

Thus, in order to form phosphoric acid by slow combustion, an apparatus must be employed which admits of the air being renewed without admitting any current ; and to keep this apparatus at a temperature of about 15 degrees, a funnel placed upon a flask, and covered with a piece of paper pierced with some small holes, in which are placed some sticks of phosphorus, is the most convenient of all : this method was suggested by M. Sage. We soon see the surface of the phosphorus covered with a coat of liquid, which flows gradually into the flask.

The phosphorus burned in this apparatus produces thrice its weight of phosphoric acid.

Messrs. Lavoisier and Laplace have calculated, that 100 grains of phosphorus absorb by combustion, 65,62 of oxygen.

We may also burn phosphorus by decomposing some acids over it.

M. Westrumb observed, that the oxy-muriatic acid inflames phosphorus, and occasions the production of its acid.

Lavoisier announced, in 1780, that we may obtain eight or nine ounces of phosphoric acid by decomposing two pounds of nitric acid, the weight of which is to that of distilled water :: 129,895 : to 100,000, upon two ounces six grains of phosphorus.

When we decompose the nitric acid over phosphorus in close vessels, there is almost constantly produced phosphorated hydrogen gas, which takes fire in the interior of the apparatus.

It would seem, according to an experiment of M. Wieglieb, that the nitric acid may be decomposed over phosphorus, even when it is engaged in a base:—by pulverizing, in a glass mortar, 100 grains of phosphorus and 480 grains of pure and dry nitrate of potash, there is suddenly produced a very brisk detonation.

M. Sage remarked, that we might revive most of the metallic oxydes by means of phos-

phorus; and that in all cases there is a formation of phosphoric acid.

It would seem, that phosphorus has also the property of decomposing water, particularly when we assist its action by means of gentle heat and long digestion.

The phosphoric acid is white, inodorous, and of a sour taste, without being corrosive.

It reddens the blue vegetable colours, and restores those which have been altered by the alkalis.

Its specific gravity varies according to its degree of concentration. We may dephlegmate it, even to vitrification; and under this form, it may weigh three times more than a similar volume of water. The acid the nearest to this state is thick and syrupy; it flows like turpentine.

Phosphoric acid distilled in a violent fire; is not decomposed; there rises—1st, water, which brings with it some atoms of acid; 2d, some portions of phosphorus, which were dissolved in the acid.

Concentrated phosphoric acid, without being dried, unites to water with effervescence: La-

voisier having mixed four drachms of this acid reduced to a syrupy consistence, with a similar quantity of water, Reaumur's thermometer rose from eight degrees to fourteen and an half. Lassone and Cornet, having employed an ounce of acid, the density of which was to that of water :: 19 : at 8 degrees, obtained an augmentation of heat of 38 degrees.

SECTION V.

Of the muriatic acid.

The muriatic acid is also known in the arts by the name of *spirit of salt*, or *marine acid*. The denomination of muriatic acid was given to it, because marine salt or muriate of soda forms the brine (*urias*) of sea-water.

This acid has a pungent smell, almost analogous to that of saffron, when it is perceived at a distance : it is in general lighter than the sulphuric and nitric acids ; its ordinary concentration for the purposes of commerce, is between the 20th and 22d degree of Baumé's areometer ; it exhales, when concentrated, a whitish vapour, which is only sen-

sible when the vessels are uncorked which contain it.

This acid precipitates silver and mercury from their solutions in nitric acid, and forms with these metals salts insoluble in water. It has a very energetic action upon the metallic oxydes, and almost none upon the metals.

It is susceptible of surcharging itself with oxygen, which increases its elasticity, renders its smell extremely irritating, and disposes it to dissolve the metals, in order to form with them caustic salts, almost all volatile, and the most of them of a pasty consistence, or like beer.

The muriatic acid may be liberated from its combinations in dry vapours, which are dissolved in water with heat and avidity.

Almost all the muriatic acid used in the arts, proceeds from the decomposition of the muriate of soda; but this decomposition is infinitely more difficult than that of the nitrates when we operate with the bolar earths, and it is always incomplete.

The white clays, and the white quartz flints cannot disengage this acid: 10 pounds of flint reduced to powder, and distilled over a violent fire with two pounds of salt, only yielded me

a roasted mass of the colour of litharge : the phlegm collected in the receiver was not sensibly acid.

The calcined bolar earths do not separate the acid from the muriate, whatever is the proportion of the mixture or the heat employed. These same calcined earths do not produce any better effect when moistened with water.

The best bolar earth for decomposing the nitrates, when mixed in the proportion of two parts to one of muriate of soda, and distilled in retorts, and with an apparatus exactly similar to that used in the distillation of aqua-fortis, decomposes the muriate in part. But this decomposition is never complete ; and the acid obtained in the receiver is always weak, unless it is dephlegmated, in order to collect separately the last vapours which pass over.

Twenty-five pounds of salt and 50 pounds of earth, never produced any more than 10 or 15 pounds of acid, at 18 degrees.

The difficulty of decomposing the muriate of soda by the intermedium of bolar earths, has caused this process to be abandoned, in order to make use of sulphuric acid only, which presents three greater advantages : no foreign

production is mixed with the acid, which condenses in the receiver ; it is the most common and the cheapest of all the acids which can be employed for this purpose ; it forms with the alkaline base of the muriate, a salt which may be found in commerce by the name of Glauber salts, after having dissolved and crystallized it, and from which the soda may be extracted by the processes of which we have already spoken under the article soda.

But in order that the decomposition by the sulphuric acid should unite all the advantages we can desire, there are some precautions with which it is necessary the distiller should be acquainted.

When we employ the concentrated acid of commerce, the mixture is heated, bubbles up, the acid passes to the state of vapours, dry, white, and almost incoercible ; so that we run a risk of breaking the vessels, of seeing the mixture pass from the retort into the receiver, and of not being able to retain and condense all the vapours. In this case it is convenient to employ the apparatus of Woulf, and of passing the vapours through water, to effect the solution of it. The salt is decomposed by

employing half its weight of sulphuric acid; and we put into the flasks of the apparatus, a weight of water equal to that of the salt employed. This process is also very generally employed in the laboratories.

But in the arts, where economy in the manufacture of the products, and simplicity in the methods, are of the first necessity, the muriatic acid has been made by another process.

In place of employing the concentrated acid, the water of the chambers, as it is called, marking 40 degrees, is used, and it is mixed with an equal weight of marine salt bruised. The mixture cannot be decomposed without the assistance of heat, so that we must pour the acid into the retort, add bruised marine salt to it, and lute the apparatus without any fear of losing any muriatic acid: a receiver is adapted to each retort, which is plunged into water; and in order to avoid all accidents, vent is given to the first incoercible vapours, by luting a crooked tube to the tubulated orifice of the receiver, and plunging it in a flask containing water. The acid vapours are condensed in the receiver, and we obtain nearly weight for weight for the salt

employed. The acid marks from 20 to 22 degrees.

The most sure and simple manner of luting the apparatus, consists in applying a slight coat of fat luting upon the joining of the receiver to the retort, and to lay over it the same luting which is employed in luting the retorts. The latter hardens at the first impression of the heat, and fixes the other in such a manner that there is no loss, and there is never any occasion to repair it.

It is prudent to take care of the fire at the beginning, and to graduate the heat so as to prevent all accidents. I have seen, after long experience, that this simple process unites all the advantages which can be desired,

Others distil in the sand-bath ; and adapting several bell-glasses to the retort, they lute them with the greatest care ; but these complicated apparatus are useless.

We have nothing else than hypotheses upon the nature of the constituent principles of the muriatic acid. Nevertheless, we see this acid is formed almost every where ; it is almost inseparable from the nitric acid ; and it is probable that we shall soon acquire some more precise

notions upon a substance, equally abundant in nature as it is precious to chemistry and the arts.

Although there are some of its constituent principles with which we have lately become acquainted, and that, by combining it with oxygen, particular properties are given to it, which renders it one of the most curious and most employed acids in the arts; it is the celebrated Scheele, of Kœping, to whom we are indebted for this interesting discovery: he published it in the Memoirs of the Academy of Stockholm, in 1774, and made known this singular production by the name of *dephlogisticated marine acid*. This acid is generally known at present by the denomination of *oxygenated muriatic acid*.

This celebrated man did not confine himself to teaching us the method of extracting this acid; he established the principal properties of it by rigorous experiments, and ascertained, that it turned cork yellow; that it destroyed the blue vegetable colours without recovery; that it oxydated the metals, and that, in every case, it assumed the character and qualities of the muriatic acid.

Since the time of this illustrious Swedish chemist, the method of manufacturing this acid has not only been simplified, but the most fortunate applications have been made of its properties to the different processes of the arts; and it has been seen, that for a long time it was formed, without being doubted, as well by composing the nitro-muriatic acid, as by combining the muriatic acid with metallic oxydes; and that most of the salts formed with these substances, are indebted to them for their bitterness, causticity, and volatility.

At present, the oxy-muriatic acid has become of such an extensive use, and it has opened such a brilliant career for the chemical doctrine, that we cannot dispense with dedicating an article to the subject, in a treatise on Chemistry as applied to the Arts.

When we wish to obtain the oxy-muriatic acid for the purposes of a laboratory, we put into a retort in the sand-bath, a part of the oxyde of manganese, well bruised, upon which we pour about thrice its weight of concentrated muriatic acid: we then adapt to the retort Woulf's apparatus, composed of a receiver, and three or four flasks, half filled with water.

As soon as the apparatus is luted, the distillation is begun by heating the sand-bath.

I make use of a still more simple process, when one or two flasks only of this acid are wanted: I put the mixture in a common phial, and afterwards adapt to the neck of it a cork which fits exactly, and through which a crooked tube passes, one end of which enters into the phial, while the other opens into a flask filled with the water we wish to acidulate. The action is assisted by means of heat, by applying warm ashes, or inflamed coals, to the phial.

The necessity of rendering the process more simple, and less expensive, in order to employ the acid in the arts with more advantage, has suggested the substitution of the following composition in place of this first mixture: it is formed of two parts of sulphuric acid, three of well dried and bruised muriate of soda, and one of oxyde of manganese, pulverized with the greatest care. It is necessary previously to dilute the acid with about half its weight of water, and to divide the oxyde and the muriate properly: without these precautions we should only obtain common muriatic acid.

The oxy-muriatic acid which passes, in the state of gas, into the receiver, has a greenish colour, a brisk disagreeable smell, very irritating, and very styptic; it burns the throat, occasioning a dry cough, followed by a spitting of blood when breathed too long.

Water, which is the most common excipient made use of for fixing this gas, only takes a small quantity of it at the temperature of the atmosphere, as proved by *André Gallish*; but it dissolves much more of it when its temperature is lowered: it is sufficient to descend three degrees below the freezing point for obtaining this acid in the concrete state: it then resembles honey diluted in some liquid. This concrete state is a true crystallization of the acid: we may recognize in it the form of a quadrangular prism, truncated very obliquely, and terminated by a lozenge. We also sometimes see upon the surface of the liquor, cross hexedral pyramids. It is only requisite to surround the vessels with pieces of ice, in order to obtain the oxy-muriatic acid in a concrete state.

The fears which attend this operation are, lest the lutings, or the corks, should give way;

lest the matter should boil up, and not pass over into the receiver ; lest the residue should thicken, in place of not flowing freely ; and lest the vessels should break.

In the first of these cases, the smell will announce the loss of the gaseous matter ; and we may ascertain the aperture by which it has escaped, by passing over the tubulures of the retort a feather dipped in ammonia ; as soon as the ammoniacal vapour comes in contact with the oxy-muriatic gas, there is formed a cloud of white and thick vapours, which will point out the hole by which the acid gas issues.

If the matter boil so as to give reason to fear that nothing is passing into the flasks or receivers, which may be occasioned either by a too much concentrated sulphuric acid, or by too brisk a heat, the door of the fire-place ought to be opened, and the heat moderated by all possible means.

The residue thickens when the action of the fire is too much prolonged, when the manganese is employed in too great a dose, or when we allow the residue to cool completely in the sand-bath before pouring it out. There is only one method of remedying this inconvenience,

which is, to dissolve the residue with the assistance of warm water.

When the vessels break, which may happen from some defect in the glass, by the introduction of a sulphuric acid too hot or too concentrated, or by the application of a too brisk heat, there is no other remedy than to take off the vessels, to pour the mixture into a new matrass, and to continue the operation with care. I have often executed this manœuvre in a manufactory, where I managed, on one and the same furnace, four large retorts in the naked fire.

At present, as the oxy-muriatic acid is very much in use in some manufactories, they are in the habit of preparing it in a very large way, by processes as simple as they are economical. We may read in the *Art of Dyeing*, by Messrs. Berthollet, sen. and jun. the description of the process generally used for its preparation: we shall here confine ourselves to saying a few words upon the apparatus established by M. Widmer, in the beautiful painted cotton manufactory of M. Oberkampf, at Jouy.

A large glass receiver *a* (*Fig. 11, Plate I.*), intended to receive the mixture, is placed upon

a small sand-bath *b*, the edges of which do not touch the sides of the furnace *c c*, so that the combustibles lying upon a grate constructed above *d d*, heats the receiver in every part of it. The receiver is terminated by a long neck *e e*, which comes out of the furnace by passing through the flue of the dome.

To the long neck of this receiver there is adapted a crooked tube of glass *ff*, which enters a flask by a tubulure made at the swell *g*; from the neck of this flask there rises a tube *h h*, as long as the tub receiver is deep; and from the middle of the swell, in the part opposite to the first tubulure, there issues another tube *i i*, crooked at right angles, which enters the tub-receiver, and opens, by a crooked beak *l l*, under the last of the caps we are about to describe. All these tubes are fastened with fat luting, and pieces of wet bladder tied on with packthread. Water is placed in the flask *p p*, into which the tube of safety enters.

The tub-receiver *m m*, called by this name because it is intended for receiving the product of the operation, is of a square form: it is nearly five or six feet deep by three or four in diameter; it is made of unhewn stone; and its

interior presents three stone caps inverted, *nnn*, placed at equal distances from each other, and only leaving between each an interval equal to their thickness : this receiver is filled with water. The glass tube which enters into it, is fastened in a groove, or spout, made in the side ; its crooked extremity, as we have already observed, opens into the cavity of the lower cap, and the gas which is brought there by this tube, displaces the water, and occupies all its capacity : it mixes or dissolves with the liquid, in a quantity so much the greater as the weight of the column of water which its elasticity is obliged to overcome is more considerable. The portion of gas which is not dissolved enters a pipe, which directs it under the cavity of the second cap ; it displaces the water of it, and is partly dissolved : but what escapes proceeds by another pipe into the third cap, the water of which is also displaced ; and, lastly, the little gas which is incoercible, is received into a funnel inverted upon the pipe of the third cap, and conducted above the roof, where it is lost by means of a long glass tube.

The stones which form the tub, as well as

the three caps, are strongly varnished with a coating of wax, resin, and turpentine, melted together, and applied with a brush. This is the varnish I have mentioned for coating the walls of apartments, intended to supply the place of lead in the manufacture of oil of vitriol.

In order to extract the acid from the tub-receiver, there is a syphon of glass *ooo*, the shortest branch of which reaches the bottom, and is there fixed, while the other branch is shut at its extremity with a cork, which it is only necessary to remove in order to cause the liquor to flow. This liquor is received into a lead pipe, terminated by a handle of leather, very moveable and supple, that it may conduct at pleasure the acid into the tub where it is to be employed. As the acid flows out, water is poured into the tub-receiver.

We see, by the description of this apparatus, that the water successively displaced from the cavity of the three caps presents large surfaces to the gas; that, on the other hand, the displacing of the water, and its elevation in the tub, which is a consequence of it, occasions a very considerable pressure, and always acting

upon this same gas ; so that the solution ought to take place with advantage.

We see also, that the most concentrated acid should be in the bottom of the tub, considering that the pressure is stronger there, and that the gas arrives there without any loss ; this is the reason why we constantly draw the acid from the bottom of the tub when we wish to use it.

M. Descroisilles has proposed an ingenious method for determining the strength of the oxy-muriatic acid, by the quantity which is required to discolour a given quantity of the solution of indigo in the sulphuric acid.

We may receive the oxy-muriatic acid gas through alkaline solutions, or in water whitened by lime or carbonate of lime : these substances certainly conceal its bad smell, but they must weaken its virtues *.

The oxy-muriatic acid is decomposed in the air, and by light ; it must therefore be em-

* What is known at Paris by the name of *eau de javelle*, is oxy-muriatic acid, combined with an alkali. It is used for taking out the stains of fruit, &c. from linen.

played as soon as it is made, or preserved in well corked vessels, and in dark places.

This acid abandons its oxygen gas with such facility, that it is only necessary to put it in contact with other very combustible bodies, in order to produce inflammation.

The greatest use to which it has been hitherto applied, has been in the bleaching of linen and cotton yarn. It is to M. Berthollet we are indebted for this valuable discovery; it has not only afforded us the means of procuring a finer white than by the old processes, but it shortens the operation, and does not wear the cloth.

This discovery is no longer an operation of the laboratory; it has become the patrimony of the arts; and all the great bleaching works are now established upon this principle. We shall describe in a cursory manner the process which appears to us the most perfect. As the process of bleaching consists in the alternate employment of leys, and immersions in the oxy-muriatic acid, we shall begin by describing the most simple method of leying.

We have been acquainted for many years with the process by which the natives of the

East bleach their cotton : I practised this process at Montpellier with the happiest success ; and it is the only one at present known :— we may therefore regard it as constant in its effects, and advantageous in its results. The apparatus consists of an oval boiler, about six feet high by five in diameter. The bottom of this boiler is of copper, and the sides are of the same metal, to the height of 18 inches : the rest of it is of good hewn stone. The upper aperture of the boiler is 18 inches in diameter, and it is closed with a round copper or stone cover. Upon the edges of the boiler, which forms the base of this kind of Papin's digester, we place a frame or grating made of pieces of wood, which leave a small interval between them. Under this oval boiler is the fire of the furnace, intended to give the necessary heat to the operation.

We generally operate upon 300 or 400 pounds of cotton thread, arranged in the form of mats : we begin by leying 100 pounds of pulverized Alicant soda, with a convenient quantity of water for forming a ley which marks two or three degrees. We place a layer of cotton in a trough, and it is sprinkled with this ley, so as to impregnate it strongly and equally : for

this purpose it is trampled upon with wooden shoes until it is well saturated. This first quantity is carried to the boiler, and arranged upon the bars which form the grating we have mentioned. A second quantity is treated in the same manner, and then placed in the boiler upon the first one; and we go on in this manner until all the cotton is employed. The boiler is then closed, and the orifices stuffed up, that the vapours may not escape: a great part of the ley which moistened the cotton flows into the lower part of the boiler, and there forms a stratum capable of preventing it from suffering by the destructive action of the fire. The fire is then lighted, ebullition is produced, and continued for 36 hours. The heat is communicated to the whole mass; the alkali which drenches every part of it, absorbs the colouring principle; and at the end of the 36 hours, the cotton has acquired a very agreeable whiteness. It is carefully washed, and then employed in the manner for which it was intended.

Here ends the operation of bleaching cotton intended for weaving.

But when we want to give it a finer white,

it may be passed through a ley of oxygenated acid, exposed in the meadow, and then blued.

This method of leying is certainly the most advantageous ; it is at the same time the most economical. The constant heat which is impressed upon the whole mass is from 85 to 90 degrees of Reaumur, while that of the ordinary leys is never more than 70 or 72.

All the mass receives an uniform action, while by the ordinary method of running the leys, false shades, as they are called, are formed, by which the liquid escapes, and a great part of the stuff undergoes its action.

I suggested and executed this method for domestic washing : the first experiment of this kind was made in the manufactory of Messrs. Bawens, at Bons Hommes, near Passy, upon 200 pairs of sheets belonging to the Hotel-Dieu of Paris. The linen was perfectly cleaned and bleached, and the expence, of which an exact account was kept, in order to be compared with that of the ordinary method, was as four to seven. I repeated the experiment, employing equal quantities of soap and soda : the linen came out whiter, and this last method ought to be always preferred, when

fine linen is washed. When the linen is thus leyed, it is only necessary to wash it carefully in pure water. I have given the details of this operation in the *Annales de Chimie*, vol. xxxviii. page 291.

Since I published this process, Messrs. Cadet de Vaux, Curaudau, and others, have devoted themselves to the subject, and have added both facility and advantages to the operation.

M. Widmer has added to this process of leying, by raising, with the help of a pump, the ley of the lower boiler to the top of the bucking tub, where it is spread by four pipes pierced with a range of small holes through their whole length, in order to pour it upon all the surface. These tubes are moved in a circular manner, by a movement impressed upon the body of the pump. The ley filters through the layer of stuff or thread, and falls back into the boiler, from which it is raised again by the pump.

This apparatus has the advantage of making the leys flow at the constant degree of boiling water, and to produce a great saving of time

and combustibles in the operation. The longest leying does not last six hours.

As linen thread and yarn is much more difficult to bleach than cotton, two leys are given to these before passing them through the acid.

The yarn is washed with great care on taking it from the bucking tub, and it is placed in a basket which is plunged into a bath of oxymuriatic acid, and which is repeatedly lifted up and down by means of a crane: this manœuvre is continued by causing new acid to flow upon it as the first portions lose their force, until the yarn will not become any whiter.

We then proceed to another washing; then a third, and thence to a new immersion.

We renew the leys to the number of seven, always accompanying them with the immersions in the acid, which is employed in a much weaker state after the fourth. The yarn, &c. is washed after every operation.

Generally, after the fourth immersion, and at coming out of the washing-tub, the yarn is passed through a bath, slightly acid, formed

by some milk or sulphuric acid, weakened until its acidity resembles that of citron juice. The yarn is plunged in by handfuls; it is then thrown into another, where it is left a day or two, taking care to drench every part of it in those bath.

The washing which precedes and follows the bath of sulphuric acid, should be done with more care than those preceding.

After the ley which follows the acid bath, the yarn is exposed upon the meadow for six days, in order to take off a yellowish shade, which the action of the air and of the light dissipates more easily than the oxy-muriatic acid.

We wash it and pass it through the oxy-muriatic acid, then through the acidulated water, and we renew the successive action of the leys, of the oxygenated acid baths, and of the acidulated water, to the eighth and last ley, in which we put soap which is dissolved in the alkaline ley.

We then expose it in the field for three days, and we finish the operation by blueing it in the following manner:

Fine azure blue is diluted in pure water;

this is made to flow through a silk sieve into a tub filled with limpid water. The workman passes the yarn into the water, wringing it, and adding water charged with blue, in proportion as that of the bath is exhausted. The yarn is then carried to the wringers, and dried in the open air. If we want to azure gauzes or lawns, a little starch must be added to the water.

Cottons do not require so tedious a course of operations, nor so strong an acid, as linen yarn or thread ; they only require four immersions at most.

Webs of linen or cotton require some modifications in the manipulations rather than in the process itself. Nevertheless, it is necessary to free them from all kind of gum before making them undergo any other operation ; and this is done in the following manner :

The webs are allowed to steep for some time in bucking-tubs full of water : a fermentation takes place, which destroys the size with which the weavers cover the threads, in order to facilitate the action of the stay of the loom. This operation of taking off the gum, is more or less tedious according to the temperature.

In order to wash the webs, we may employ two wooden rollers, placed above each other upon supporters fixed in the current of a river; the upper one has channels cut in it, parallel to its axis; it is fixed by pivots fastened in a groove made in the supporters; these pivots are not fixed down so that this cylinder may rise freely, and throw all its weight upon the other. When we wish to wash a web, one end of it is fixed between the cylinders, and by turning the handle of one of the pivots, the cloth flows rapidly through the cylinders, and is strongly squeezed by the upper one, which presses upon it with all its weight.

M. Descroisilles, who established one of the first cotton bleach-works by the oxy-muriatic acid, and who to this day produces a white, which his cotemporaries cannot imitate, puts the cottons into large bucking-tubs, and makes the oxy-muriatic acid flow through them.

In almost every manufactory, attempts have been made to correct the insupportable smell of this acid, either by means of carbonates of lime or pure lime; or by the alkalis; but they have been always made to the detriment of the virtue of the acid. Chalk, of all other

substances, is that which alters its properties the least, and which nevertheless corrects its bad smell; it is therefore always mixed with the acid at the moment of using it.

As this acid is easily decomposed, and for this reason the carriage of it is almost impossible, when we wish to bring it to the work-house we are under the necessity of combining it with lime or the alkalis: in both cases it is less powerful, and its action slower, but is more concentrated, and it is decomposed with more difficulty. It belongs to those who use it to balance the difficulties and disadvantages which attend it.

This acid is also very valuable in the dyeing and colouring of printed cloths, from the virtue it possesses of destroying the vegetable colours. We may by this means discharge the colours from a piece of cloth, the design of which we wish to alter, and restore it to its primitive whiteness.

In speaking of the properties we have now ascertained to belong to the muriatic acid, I have extended its application to the bleaching of copper-plate engravings and old books, as well as of the paste or rags of which paper is

made. *Vide* my Memoir in the volume of the Academy of Sciences for 1787; and the *Annales de Chimie*, volume i. p. 69.

M. Loysel has given some new details upon the method of bleaching the paste of which paper is made. *Vide* the *Annales de Chimie*, volume xxxix. p. 137.

As to the bleaching of copper-plate engravings, it is only necessary to soak them in the acid for a few minutes, and to pass them afterwards through clean water, to take away all the smell. It will necessarily occur, that when a book is to be bleached, it must be cut to pieces, and operated upon in sheets.

This acid has the property of destroying writing-ink, without hurting that used for printing, which is a different composition; and it is made use of for taking out the stains of ink and written names, which very often diminish the value of books and prints.

It may be also used with advantage for correcting the vitiated atmosphere of prisons, and generally for destroying and burning all the deleterious miasmata, which are the most ordinary cause of contagious maladies. The

nitrous and muriatic acid have been successively employed for this purpose. We are indebted to M. Guyton Morveau, for the first lessons of experience upon the virtues of the latter : but there is no doubt that the oxy-muriatic acid is preferable to all of them ; because it is not only more elastic, more evaporable, but it burns and destroys the miasmata it touches ; and were it employed in preference to the other acids, it would produce far greater effects. The only inconvenience which attends its use, is the insupportable smell which exhales wherever it is, and the impossibility of breathing any where at the time it is poured in vapours.

SECTION VI.

Of the nitro-muriatic acid.

What is called *aqua-regia* in commerce, is the mixture of the two acids we have already mentioned : viz. the nitric and muriatic. The name of *aqua-regia* has been given to this mixture, because it is the only acid which dissolves gold, the king of the metals.

Aqua-regia is characterized by a smell, which differs little from that of the oxy-muriatic acid.

It is generally of a yellow colour.

We obtain this mixed acid by several processes, which we shall successively detail.

1st, The distillation of common saltpetre furnishes a nitro-muriatic acid, which may be made use of for dissolving tin and gold.

2d, The simple mixture of the two acids in the proportion of one part of muriatic acid to three of nitric acid, forms *aqua-regia*.

This mixture raises Reaumur's thermometer three degrees, and when it has resumed the temperature of the atmosphere, neither augmentation of density, nor penetration can be discovered. M. Guyton having mixed two parts of nitric acid, the specific gravity of which was 1,209, with one part of muriatic acid, of the specific gravity of 1,126, the thermometer marking 15 degrees; the mixture produced a heat of three degrees; the specific gravity of the mixture was 1,1795, while upon calculation it yielded 1,1813. He attributes this slight difference to the rarefaction occasioned by the heat, and concludes that there is neither aug-

mentation of density, nor penetration. The acids, which are clear like water at the time of mixture, become yellow a short time afterwards; and a slight effervescence takes place, which is owing to the liberation of some bubbles of oxy-muriatic acid.

3d, We may also obtain aqua-regia by distilling nitric acid over muriates, or muriatic acid over nitrates.

In the first case, Baumé recommends distilling two ounces of muriate of soda and four ounces of pure nitric acid, at 35 or 40 degrees, in an apparatus in the sand-bath.

We may substitute muriate of ammonia in the place of muriate of soda; but then it is necessary that the decomposition should take place in the cold. Four ounces of muriate of ammonia in powder, gradually mixed with 16 ounces of nitric acid, form an excellent aqua-regia; but the mixture works a long time, and a vent must be left for the vapours, otherwise they would break the vessels.

Boerhaave recommends the distilling of two parts of muriatic acid with one of very pure nitrate of potash, for producing a good aqua-regia.

Cornette asserts, that six drachms of smoking muriatic acid completely decomposed four drachms of nitrate of soda, and that the vapours which arose were those of aqua-regia. *Vide* the Memoirs of the Royal Academy of Sciences, for 1778.

By decomposing at one and the same time the nitrates and muriates by the sulphuric acid, we obtain aqua-regia. Boerhaave obtained it very good by distilling two parts of nitrate, five of muriate of soda, and three of sulphate of iron.

But whatever process is employed, it seems that the proportions should vary according to the use to which we wish to apply it.

Experience has shewn, that the aqua-regia, which is the most proper for dissolving gold, is composed of three parts of nitric acid, and one part of sal ammonia dissolved in it.

Brandt has suggested (*Memoires de Stockholm*, 1753), that the nitric acid should be heated over gold, and common salt afterwards added in small quantities. He asserts that the solution is more easily and more speedily made.

Those chemists who have examined platina,

have suggested the mixture of equal parts of the nitric and muriatic acids.

Macquer recommends an aqua-regia strongly charged with muriatic acid, when we wish to dissolve tin. That which contains one-third of muriatic acid can hold in solution an equal weight of tin, without precipitating it.

Aqua-regia has properties which none of the acids share that compose it. As soon as the mixture of the two acids takes place, bubbles are seen forming and escaping, which are oxy-muriatic acid; at the same time the aqua-regia becomes yellow. It seems beyond doubt, as M. Berthollet has published, that a portion of the oxygen of the nitric acid acts upon the muriatic acid, and causes a part of it to pass to the oxygenated state: this is what occasions the smell which is developed, and the bubbles and vapours which escape: at this time a portion of the nitric acid, brought to the state of nitrous gas, is dissolved in the two acids, and colours them yellow.

It is not the oxy-muriatic acid which produces the peculiar effects of aqua-regia, since it is exhaled; neither is it the nitrous gas which is eliminated by the action of the metal;

but it is the concurrence of the two acids, the nitric and muriatic, one of which is decomposed, and furnishes its oxygen to the metal, while the other dissolves the oxyde as fast as it is formed.

SECTION VII.

Of the fluoric acid.

Although this acid was not known until 1771, and although its application to the arts is not very extensive, I think it right to mention it, because it has properties which no other acid possesses in common with it; and because I foresee that, in putting it into the hands of artists, they will soon derive some advantages from it, and will regard it with gratitude, as one of the most valuable gifts which chemistry is every day bestowing on the arts.

This acid is extracted from *fluor spar* (*vitreous spar*, *phosphoric spar*, *fluat of lime*); the name of fluoric acid has been therefore given it.

So early as 1768, the celebrated Margraaf had published, in the Memoirs of the Berlin Academy, that eight ounces of *fluor spar*,

white and green, calcined and distilled with eight ounces of sulphuric acid and three ounces of water, formed a white sublimate, and *pierced the retort with holes, as if it had been fired at with small shot.* But it was reserved for Scheele to prove, some years afterwards, that this effect was owing to a particular acid, which corrodes glass and dissolves quartz; and which, combined with lime, forms fluor spar, from which the sulphuric acid may drive it, and make it visible in the form of white pungent vapours, &c.

Thus, in order to prepare and extract this acid, we begin by calcining and pulverizing the spar; we then introduce it into a retort, and pour upon it an equal weight of concentrated sulphuric acid: we stir the mixture afterwards with a glass tube inserted into the tubulated neck of the retort, so as to moisten or penetrate the whole mass with the acid. The retort is placed in the sand-bath; a receiver is adapted to it, in which has been put a quantity of water equal to the weight of the spar employed: the joinings must be luted carefully, and the apparatus suitably heated.

We soon see white vapours rise from the

mixture, and fill the retort; the mixture boils, and the vapours which continue to be liberated are fixed upon the sides of the receiver and the retort, or dissolve in the water, which they render acid.

Scarcely had Scheele published this discovery, when some chemists attacked his opinions: some regarded this acid as a natural combination of the muriatic acid with some earthy substances; others thought, that it was only a modification of the sulphuric acid employed in the experiment.

The former founded their opinion, 1st, Upon the particular smell of the fluorio~~ic~~ acid, being very analogous to that of the muriatic acid: 2d, Upon the circumstance of the fluoric acid precipitating silver and mercury from their solutions.

The latter founded their opinion chiefly, upon the circumstance of the acid obtained surpassing in weight the spar employed.

Scheele answered the first, that the precipitation of the metals only took place when the acid contained a little muriatic acid.

The partisans of the latter opinion were deceived by the portion of silex the acid takes

from the retort or the receiver, which ought necessarily to increase the weight of the acid which passes over in distillation.

It is now beyond all doubt, that the fluoric acid is an acid *sui generis*, enjoying all the characteristic properties of the acids, and possessing exclusively the astonishing faculty of dissolving and volatilizing silex : it is to this last property we ought to attribute the corrosion and destruction of the glass vessels in which this acid is distilled. The pellicle formed on the surface of the water of the receiver in which the acid is dissolved, is owing to the silex abandoning the acid as fast as it is dissolved.

We may render this phenomenon very interesting, by plunging in water the extremity of the retort, or of a tube, by which the fluoric acid charged with silex escapes in vapours ; at every bubble which escapes we see a whitish pellicle detached, which rises in the liquor, and the number of which soon represents a semi-transparent mass, which floats in the liquid : this substance is merely silex in a very minute state of division.

This siliceous earth is furnished to the acid,

not only by that which forms the base of earthen vessels, but also by the fluete of lime itself, which is rarely exempt from it.

In order to obtain an acid perfectly pure, Scheele suggested the employment of metal vessels in the distillation of it, and Meyer put this idea in practice; he took three vessels of tin, of equal capacity, and put into each a mixture of three parts of sulphuric acid, and one of fluete of lime pulverized in a metal mortar: he added to one of these mixtures, one part of pulverized glass; to the other, one part of quartz in powder; and nothing at all to the third: he suspended a sponge, drenched with water, above each mixture; and after having closed the vessels, he applied a moderate heat to them: half an hour afterwards, the sponge belonging to the first vessel was covered with siliceous crust; twelve hours afterwards, the same phenomenon took place in the second; and the third did not shew the slightest trace of silex, even after several days.

From these results it is well proved, that we may obtain the fluoric acid almost pure by employing lead or tin vessels; I say *almost*

pure, because experience has shewn, that the best crystallized and whitest fluor spars always contain and yield a little silex. Ammonia constantly discovers some atoms of it in that which may be regarded as the purest. Bergman found $\frac{1}{800}$ of it in the acid, the specific gravity of which was as 1064, that of water being supposed at 1000.

This acid is preserved in metal vessels, or in glass flasks, coated with wax throughout all their interior surface.

The arts have already profited by the property possessed by this acid, of dissolving silex, for engraving upon glass, and tracing cyphers or making divisions on that substance.

Messrs. Klaproth and Puymaurin, nearly at the same moment suggested this method, which the artists have already perfected :

A coat of engraving varnish is laid upon the surface of the glass; the design is drawn which we wish to engrave, by uncovering the glass wherever the drawing passes ; fluoric acid is afterwards poured on, which corrodes the glass more or less deeply, according to its strength, and the time we allow it to remain. We see that this process is absolutely the same

with that of the engraving of aqua-fortis. In place of employing the liquid acid, we may expose the plate to the vapour ; the corrosion is still more speedy.

M. Luthen of Wolfenbuttel, suggests a better varnish than that of the engravers ; it is a coating of fish glue.

When the acid is not very strong, its action must be assisted by raising its temperature some degrees, which may be effected by carrying the plate of glass into a warm place, and leaving it there until we think the impression deep enough.

This method of engraving will become valuable for tracing the scale or the degrees on all the glass instruments exposed to the action of the air, water, or friction, as we need not be afraid of the alteration or destruction of the figures.

SECTION VIII.

Of the boracic acid.

This acid, known until lately by the name of *sedative salt of Homberg*, is one of the principles of borax, in which it is combined with soda.

It is, however, found in a free state in some waters of Italy : Hoefer has successively extracted it from the water of lake Chierchiajo, near Monte-Rotundo, in the lower province of Sienna, and from that of the lake of Castello-Nuovo : the former, which is very hot, and from which a sulphureous vapour exhales, furnished him with three ounces of this acid in 120 pounds of water ; the latter yielded 120 grains out of 12280 employed in the analysis. This chemist presumes, that the lakes of Lasso, Monte-Cerbeloni, &c. contain it also.

Independently of the existence of this acid in the waters we have mentioned, it is found engaged in natural alkaline or earthy combinations, such as the *cubical quartz of Lunebourg*, in which M. Westrumb found it mixed with lime, magnesia, alumine, and silex, in the proportion of six-tenths.

But all these facts, which prove that the boracic acid is more extended than was thought, do not furnish it in a sufficient quantity for extracting it with advantage ; and it is exclusively from the decomposition of borax that it has been hitherto extracted.

It was in 1702 that, for the first time,

Homborg decomposed borax, by distilling it with calcined sulphate of iron. He designed by the name of *sedative salt*, what we now denominate *boracic acid*.

Lemery, jun. discovered, a short time afterwards, that we might extract the boracic acid from borax by the intermedium of the sulphuric, nitric, and muriatic acids.

Geoffroy was not long in proving, that soda was the base of borax.

Baron taught us, that the vegetable acids could decompose borax.

Thus, in a few years, our acquaintance with this substance became so complete, that nothing new can now be expected.

The processes daily in use for extracting this acid are only two : *sublimation* and *crystallization*.

The first of these two methods is executed in the following manner : a glass cucurbit, with its head on, is placed in a sand-bath ; the quantity of pulverized borax we wish to decompose is put into the cucurbit, and half its weight of concentrated sulphuric acid is poured above it. As soon as the heat acts upon the mixture, a leafy salt is raised,

which sticks to the sides of the vessel, and a part of which remains above the mixture, where it forms a tolerably thick coat, composed of leaves or scales of about six lines in diameter each.

This sublimed salt is *boracic acid*. What remains at the bottom of the cucurbit is sulphate of soda.

When we proceed by crystallization, the borax is dissolved in hot water, and sulphuric acid is poured upon it in excess: the mixture becomes hot; and upon cooling, there is deposited a salt, in round thin leaves attached to each other. This precipitate is carefully separated, and dried upon Joseph paper: it becomes very white, silvery, and light, and resembles the very thin scales of a fine white mica.

By repeated solutions and crystallizations, this acid is freed from every thing which could retain the substances employed in its preparation.

This acid is very susceptible of being sublimed, or of escaping into the air, even when united to water; and this is the reason why ebullition must be avoided in the various ope-

rations it undergoes : but when it is deprived of water, it possesses the greatest fixity, and vitrifies in a strong heat without volatilizing.

One pound of distilled water dissolves 183 grains of it at a boiling heat.

This acid is not altered in the air ; it reddens the blue vegetable colours, and has a salt and cold taste.

Alcohol dissolves it more easily than water, and the solution then assumes a fine green colour.

The glass produced by the fusion of this acid is white, transparent, and a little more pasty than that of borax. It does not attract humidity from the air, but it becomes slightly opaque in a few days.

This acid may supply the place of borax ; like which, it facilitates the fusion of the metals, and may be used for soldering them together.

The glass is preferable to the salt ; because the latter, in boiling up, displaces the pieces of metal we wish to solder, changes their respective positions, deranges the design of the artist, and requires the greatest possible care on his part.

SECTION IX.

Of the tartrous acid.

It was in 1770 that the celebrated Scheele taught us how to extract the tartrous acid from the combination it forms with potash, in the production known in the arts by the name of *cream of tartar*, *acidulated tartrate of potash*.

This illustrious chemist advises us to dissolve two pounds of crystals of cream of tartar in water: we then throw upon it, by little at a time, chalk, until it is completely saturated; a precipitate is formed, which is a true tartrate of lime, without taste, and gritty under the teeth; we put this tartrate into a cucurbit, pouring above it nine ounces of sulphuric acid, and five ounces of water: digestion is kept up for twelve hours, taking care to stir it from time to time. The tartrous acid is then set free; it is separated entirely from the almost insoluble sulphate of lime, by diluting it with cold water; we filter it, and obtain, by evaporation, eleven ounces of concrete acid. The evaporation should be carried on until it is of syrupy consistence, without which we cannot obtain any crystals.

In order to be convinced that this acid was not mixed with sulphuric acid, Retzius and Bergman suggest, that we should let fall a few drops of solution of lead into the liquor : there follows at the moment a white precipitate, which disappears on the addition of vinegar, if it is a tartrate of lead, and it remains if it is a sulphate. If these tests shew the presence of a little sulphuric acid, it is purified by digestion over a little chalk.

In order to obtain the acid in crystals, Bergman advises us to evaporate to the consistency of syrup, and to leave the solution in a cool place ; Peecken asserts, that it is only requisite to manage the evaporation carefully. This last process supplied me with very minute crystals, which seemed to me to proceed from elongated octahedral crystals. Bergman's process presented me with hoops, formed by tetrahedral prismatic crystals, terminated by pyramids with four very much elongated faces. I also obtained this acid in triangular scales, founded upon an angle.

The solution of this acid diluted in water, became mouldy after some time, like all the vegetable substances.

The crystals of tartrous acid are not decomposed in the air : they blacken in the fire, and leave a spongy charcoal, which becomes white at a stronger heat.

This acid, when distilled in the hydro-pneumatic apparatus, furnished carbonic acid, and also hydrogen gas.

It has a very pungent taste, reddens the violet, mallows, and turnsole colours ; displaces the carbonic acid from its combinations with the alkalis, and dissolves alumine with facility ; it is this last combination which is formed, when we employ the acidulated tartrite of potash along with alum, in several dyeing operations.

SECTION X.

Of the citric acid.

The citric acid exists abundantly in citrons or lemons ; but it is particularly mixed with an extractive principle, of which it must be freed in order to obtain it pure.

Scheele was the first who obtained this acid in a solid form. He proposes that the acid should be combined with lime, in order to separate it from the mucous principle, and that

the citrate should be decomposed by sulphuric acid in excess, diluted in water. The citric acid is dissolved in the water which was used in diluting the sulphuric acid.

Washings and filtration entirely separate the citric acid, which is evaporated in stone vessels, at the temperature of boiling water. M. Dizé remarked, that it was advantageous to suspend the evaporation every two days, in order to allow the little sulphate of lime to precipitate, which is held in solution in the liquor by the help of the citric acid.

The crystals furnished by a first evaporation are blackish, as a consequence of the reaction of the sulphuric acid, in proportion as it is condensed; these same crystals are redissolved, filtered, and evaporated three times; they are then white, regular, and present rhomboidal prisms, the planes of which inclined from 120 to 60 degrees, are terminated on one side and the other by a peak, with four trapezoidal faces, which intercept the solid angles.

The sulphuric acid should be employed in excess, in order to decompose, towards the end

of the evaporation, the little mucous principle which remained combined.

One hundred parts of citron juice absorb six and an half of calcareous carbonate.

The citrate extracted from it, forms one-fifth of the quantity of juice employed.

The pure and crystallized citric acid, takes equal parts of calcareous carbonate, in order to be saturated.

One ounce of distilled water distils an ounce and a half of citric acid, and 13 degrees (Reaumur's thermometer) of cold are produced.

Forty grains of this acid dissolved in a pint of water, and dulcified with a sufficient quantity of sugar, form an excellent lemonade.

Georgius announced, in the Memoirs of Stockholm for the year 1774, a process for purifying this citric acid from its excess of extractive, without altering the properties of it : he filled a bottle with citron juice, and having corked it closely, he deposited it in a cellar : the juice was kept four years without spoiling ; the mucilaginous parts were precipitated in flakes, and the acid became as clear as water.

In order to dephlegmate the acid, he exposed it to frost : he remarks, that this degree of cold was not too strong, because, if it were so, the whole would become one mass. The icicles may be separated in proportion as they are formed : the first are sweet ; the latter have a sourish taste. The acid thus concentrated, is eight times stronger : it only requires two drachms to saturate one drachm of potash. In commerce, when citric acid is prepared for the arts, the citron juice is fermented, in order to clear it from the extractive matter, and it becomes very limpid.

It is made use of by the silk-dyers—1st, in order to precipitate the red of carthamum from its solution in the alkalis, and to form the poppy red, orange red, and fine rose-colours, &c. or the vegetable red, when it is precipitated upon a soapy earth ; 2d, in order to orange the yellows made by the solution of *rocou* in an alkali.

It is also employed in the manufactories of printed cottons, and in taking out iron-moulds from cloths.

If this acid should become more common, or if it could be obtained by artists at a lower

price, there is no doubt that its application would be more extensive; and it is desirable that the subject should be investigated in those countries where lemons abound, and where their juice is prepared, in order to diffuse it in commerce.

SECTION XI.

Of the malic acid.

We are indebted to Scheele for the discovery of this acid also: he announced it in 1785, in the *Annales de Creel*.

As he extracted it from apples at first, he gave it the name of *malic acid*.

This acid is certainly the most diffused of all those known in the vegetable kingdom: it exists almost every where; the sweetest products, in which we should least suspect it to exist, contain it in abundance; and it is to its presence, almost inseparable from vegetation, as we shall see, that we ought to refer many phenomena which belong to vegetables.

The celebrated Scheele extracted the malic acid from apples, by saturating their juice with an alkali: he decomposed this first malate

by the acetate of lead ; dulcified the precipitate, and poured upon it weak sulphuric acid, until the liquor assumed a decided acid taste, without any mixture of sweet. The whole was filtered, in order to separate the malic acid from the sulphate of lead. This acid is very pure ; it is always liquid, and can never be brought to the concrete state.

This acid differs from the citric acid by the following characters.

1st, The citric acid crystallizes easily, while the malic constantly refuses to take a solid form. 2d, The malic acid, treated with the nitric acid, yields oxalic acid ; the citric acid, very pure and freed from all extractive, yields none. 3d, The citrate of lime is almost insoluble in boiling water ; the malate is more soluble. 4th, The malic acid precipitates the solutions of nitrate of lead, mercury, and silver ; the citric acid produces no change. 5th, The malic acid is displaced from lime by the citric.

The celebrated Scheele has left us the following table of such fruits as furnish it pure, or mixed with other acids :

Juices extracted from the fruits of

The barberry-tree— <i>Berberis vulgaris</i> ,	}	Produce a great deal of malic acid, and little or no citric acid.
The elder-tree— <i>Sambucus nigra</i> ,		
The prickly plumb tree— <i>Prunus spinosa</i> ,		
The service, or roan-tree— <i>Sorbus aucuparia</i> ,		
The garden plumb-tree— <i>Prunus domesticus</i> ,		
The cultivated vine, verjuice,		
Green gooseberries— <i>Ribes grossularia</i> ,	}	Seem to contain one half malic, and one half citric acid.
Red gooseberries— <i>Ribes rubrum</i> ,		
Whortleberries, or bleaberries— <i>Vaccinium myrtillus</i> ,		
The common white beam-tree— <i>Crategus aria</i> ,		
Cherries— <i>Prunus cerisus</i> ,		
Strawberries— <i>Fragaria vesca</i> ,		
Mountain brambleberries— <i>Rubus chamaemorus</i> ,	}	A great deal of citric, and little or no malic acid.
Raspberries— <i>Rubus idæus</i> ,		
Cranberries— <i>Vaccinium oxycoccos</i> ,		
Red bilberries— <i>Vaccinium vitis idæa</i> ,		
Common bird-cherries— <i>Prunus padus</i> ,		
Bitter-sweet— <i>Solanum dulcamara</i> ,		
Sweet-briar,	}	
Lemon-tree,		

Scheele has also proved, that the malic acid exists in sugar : in order to be convinced of this, it is only requisite to pour weak nitric acid upon sugar, and to distil until the mixture

becomes brown. We then precipitate, by means of lime-water, all the oxalic acid which is produced. We then collect the acid which remains in the liquor, by means of chalk, and decompose by the acetate of lead. The sulphuric acid afterwards disengages the malic acid by combining with lime. The juice of the sugar-cane, and the last syrups of the refinings of this substance, called *molasses*, present malic acid in a free state. It is to the existence of this incrySTALLIZABLE acid that we ought to refer the difficulty of crystallizing these syrups; and it is to this same principle we ought to attribute the necessity of employing lime for refining sugar.

Scheele also found this acid in gum arabic, manna, sugar of milk, gum tragacanth, starch, extract of gall-nuts, oil of parsley seeds; in the aqueous extracts of aloes, colocinth, rhubarb, and opium; but as he did not obtain this acid, except on treating them with nitric acid, he has not proved that they naturally exist in these substances. It may be formed, perhaps, by the decomposition of the nitric acid.

Fish-glue, whites and yolks of eggs, and the blood, treated with nitric acid very much concentrated, furnished Scheele with oxalic and malic acids.

There are few plants, and there are no vegetable products, which do not present us with malic acid : when the juices expressed from vegetables are concentrated, when they refuse to thicken, and preserve almost constantly a syrupy consistency, or fall *per deliquium*, when they are dried by a strong heat, it is probably to this acid we ought to refer all these phenomena. It is only requisite, in order to fortify this opinion, to observe, that almost all the juices contract on acidifying, a very marked acidity ; and that the most acid ones are generally those which remain the most gluey. Besides, it is known that this acid forms deliquescent salts, with the alkalis and magnesia.

All the wines I have yet analysed, have presented me this acid in a free state : the sweetest wines redden blue paper, when it is soaked some time in them : the must itself contains the acid in question. The wines of the North

furnish much more than those of the South ; and it is to this cause that I ascribe the difference observed between the spirituous liquors of the two climates. Those of the North redden blue paper ; and it is very difficult to deprive them of the acid, even by repeated distillations : those of the South, but very rarely give any proofs of the existence of an acid in their composition.

When wines pass to the state of vinegar, the malic acid disappears, and acetic acid is to be found at the moment the acetification is terminated.

Wines which are not completely sour, also furnish spirituous liquors of a bad quality, because the malic acid which exists in them passes off by distillation. These facts may throw a great deal of light upon the different qualities of spirituous liquors, and upon the art of distillation.

SECTION XII.

Of the acetic acid.

The most widely diffused, and the most useful of all the acids, is the acetic acid, better known by the name of vinegar : its economical uses, its employment in the arts, its daily formation in consequence of the degeneration of our wines, have rendered this acid familiar to every one.

Its characters are as follow :

A peculiar smell, lively without being irritating.

A sour taste, neither strong nor disagreeable.

Its colour is that of the wine which produced it ; limpid like water when distilled.

Ordinary concentration, from four to six degrees.

The spontaneous alteration of spirituous liquors furnishes almost all the vinegar which is used in the arts, and in cooking our victuals.

We shall detail the principal conditions which acetification requires : some of them are

indispensable ; all of them are favourable : we shall point out the degree of influence of the whole.

FIRST CONDITION.—*The presence in the wine of a portion of ferment, or vegeto-animal principle* *.

The manufacturers at Orleans prefer wine of a year old to that which is newly made, because this last undergoes the remains of a spirituous fermentation, which does not admit of the acid degeneration. But the wine which is freed from all its vegeto-animal principle, does not become sour ; it loses its colour without souring. I have experienced this with the old and very spirituous wines of the South, after keeping them a long time exposed to the sun. It is known that we determine the acetification, by digesting in wine, slips of vines, bunches of grapes, green woods, &c.

It would seem, upon considering all the circumstances which influence acetification, that

* It may be seen at the article *Fermentation*, in the fourth volume of this work, what is meant by the *vegeto-animal principle*.

we cannot refuse to regard the vegeto-animal principle, at least as an intermedium, or a ferment in the conversion of wines into vinegar.

SECOND CONDITION.—*The existence of a spirituous principle.*

We know this much ; that such bodies only as have undergone the spirituous fermentation, are susceptible of a spontaneous acetification : such as wines, cider, beer, &c. The most generous and richest wines furnish the best vinegars.

The addition of alcohol alone, to substances which contain some extractive principle, produces the acid fermentation in them : Stahl has already observed, that if we moisten roses or lilies with alcohol, and place them in vessels in which they may be agitated from time to time, vinegar will be formed.

The same chemist also informs us, that if, after having saturated citron-juice with crab's eyes, we mix alcohol with the liquor which swims above the precipitate that is formed, and abandon the whole to a given temperature, vinegar will be formed.

After having, by distillation, exhausted the wine of all the alcohol it can furnish, it is only requisite to sprinkle the residue with alcohol, in order to develop a fine acetous fermentation.

The extractive principle, when fermented by itself, putrefies; alcohol, by itself, undergoes no alteration: their mixture passes to the acid fermentation.

I ascertained these principles by direct experiments—1st, Two pounds of spirits of wine, at 12 degrees, in which I carefully diluted about 300 grains of beer yeast, and a little starch dissolved in water, produced extremely strong vinegar.

The acid was developed in it on the 5th day of the experiment.

2d, The same quantity of yeast and starch, diluted in water, produced vinegar; but the acid was developed more slowly, and never acquired the same strength as the former:

THIRD CONDITION.—*The contact of the air.*

No alcoholic matter undergoes the acid fermentation, if it is not in contact with the air:

FOURTH CONDITION.—*A degree of heat kept up between 18 and 20 degrees of Reaumur's thermometer.*

Acetification takes place at a degree below 20 of Reaumur ; but it is then slow ; and observation has proved, that the temperature from 18 to 20 degrees is the most favourable. In the manufactories where vinegar is made, care is taken to keep up the heat at this degree, by means of stoves, when the atmosphere does not supply it.

FIFTH CONDITION.—*A yeast or ferment.*

While the constituent principles of a body are in just proportions, or in their natural equilibrium, no change is produced. But if we make one of the principles predominate, or if we introduce a foreign one, the equilibrium is broken, the order of affinities is changed, and we give place to movements and re-actions, which change the matter of the primitive compound : this is the first effect of ferments.

We may even direct or determine the course of new operations, and ascertain beforehand the result which should follow from

them, by employing ferments of such or such a nature. It is thus that the lees of vinegar, and the casks which are impregnated with them, decide and facilitate acetification.

SIXTH CONDITION.—*A slight agitation.*

We know, that in order to preserve wine from every kind of alteration, it should be placed beyond the reach of any agitation, and in situations where the air is tranquil and the temperature fresh and equal.

A slight motion given at intervals to the cask which contains wine, a shaking occasioned in the air by any cause capable of producing a slight agitation in the liquid, are the most general causes of the alteration of wine. It is thus that in cellars which are not deep, as well as in those which are exposed to the continual shaking of any noisy mechanical instrument, or the daily rolling of carriages, the wine is preserved with difficulty. It is probable, that the effect of thunder upon wine ought to be referred to the same cause.

In every case, the first effect of the agitation is to mix with the wine, the tartar, the

lees, the extraction, and generally all the principles which are deposited by repose ; consequently the depuration, or clarification, becomes impossible : and all these substances jumbled together again in a liquor which was once cleared from them, and put again in contact with the air, furnish just as many ferments.

This doctrine agrees perfectly with all the precautions which are taken to preserve wine from alteration : it is allowed to deposit, it is decanted and fined down by means of isinglass, &c. ; and by all these operations, it is cleansed from all the principles which might provoke the acid fermentation.

After having made known the principal conditions of the acetification of fermented liquors, it remains for me to describe these phenomena.

1st, A movement is produced in the mass, and a kind of trembling motion among all the constituent parts, and which is perceptible to the eye.

2d, Heat is liberated : I have seen it so high as 25 and 26 degrees (Reaumur) in large volumes of liquid.

3d, Small bubbles are elevated and escape,

which are a mixture of alcohol and carbonic acid.

4th, The liquor becomes thick : streaks are seen agitated and moved in the heart of it, which rise up, precipitate themselves, divide, join again, and form a deposit resembling soup; from its consistency, adhering forcibly to all bodies with which it comes in contact.

When all these phenomena have ceased, and the deposit is formed, the liquor becomes clear and the vinegar is made.

In the conversion of wine into vinegar, the alcohol completely disappears; and if the distillation of vinegar sometimes furnishes it, it is because the acetification is still incomplete. I have constantly seen that the good vinegars do not furnish any at all.

All the spirituous or alcoholic liquors undergo the acid fermentation; and those which furnish the most alcohol, yield the best vinegar.

We shall here confine ourselves to wine vinegar, and that produced from grain; and we shall now enter into some details upon the manufacture of both kinds.

ARTICLE I.

Of the manufacture of wine vinegar.

In the great wine districts, particularly in warm climates, such as the south of France, the people are less occupied in devising processes for manufacturing vinegar, than in methods proper for preventing the wine from becoming so of itself; and, in spite of all the precautions they use, the quantity of wine which proceeds to the sour state, far surpasses the quantity of vinegar wanted in that district.

But in the colder climates, and where wine is of more value, the making of vinegar has been made a distinct branch.

The oldest process known, is that of which Boerhaave has left us a description: it consists in placing two wooden tubs in a warm situation; a grating, or hurdle, is placed at a small distance from the bottom. Upon this hurdle is constructed a tolerably close layer of green vines, and the vessel is filled with stalks. When the tubs are thus disposed, one of them is filled with wine, and the other only half filled.

Four-and-twenty hours afterwards, the half-filled vessel is filled with the liquor of the other one; in another four-and-twenty hours, the contents of the full cask are poured into that which had been emptied; and this manœuvre is repeated every day until the vinegar is made.

By this means, the fermentation is incessantly moderated, the fermenting mass is kept in a state of convenient motion, and the acetification is complete in 15 or 20 days. The heat of the manufactory ought to be from 18 to 20° of Reaumur.

Almost all the vinegar of the north of France is prepared at Orleans; and the manufactory of it there has acquired so much celebrity, that we may regard their processes as the best. They may be reduced to the following description, according to Messrs. Prozet and Parmentier, two excellent judges of the subject.

In the vinegar works at Orleans, they employ casks which contain nearly 400 pints of wine; those which have been already used in the making of vinegar are preferred, and they are called by the workmen, the *mothers of the vinegar*.

These casks are placed in three rows, one above another; they are pierced in the upper part by an aperture of two inches diameter, which is always open.

On the other side is kept the wine intended for the acetification, in casks, in which there is placed a layer of beech shavings, upon which the fine lees are deposited, and where they adhere. It is from these casks that the wine, finely clarified, is drawn off, in order to make vinegar.

They begin by pouring into each cask 100 pints of good boiling vinegar, and it is left there for eight days. They afterwards mix ten pints of wine in each cask, and they continue to add an equal quantity every eight days until the vessels are full. The vinegar is allowed to remain in this state 15 days before it is exposed to sale.

The mothers, as they are called, are never emptied more than one half, and they are successively filled again, as we have already said, in order to convert new quantities of wine into vinegar.

In order to judge if the mother works, the vinegar-makers are in the habit of plunging a

spatula into the vinegar, and drawing it out immediately. They see that the fermentation proceeds, and is in full activity, when the wet end of the stick presents froth on it, or *flower of vinegar*, as it is called; and they add more or less wine, and at various intervals, according as the froth is more or less considerable.

In summer, the heat of the manufactory is sufficient for acetification; but in winter, a constant heat of 18 degrees (Reaumur) is kept up by means of a stove.

In some country places they keep, in a place where the temperature is mild and equable, a cask, which is called the vinegar-cask, in which they pour such wine as they wish to make sour; and it is always kept full, by supplying the place of the vinegar they draw from it, with new quantities of wine. In order to establish this valuable resource, it is only requisite to buy, once for all, a single cask of good vinegar.

In all the wine districts, vinegars are made with the stalks of the vine, and the husks of the grape, the residue of the distillation, &c.

If we dry completely in the sun, vine-stalks, and afterwards impregnate them with a gene-

rous wine, an acid fermentation will be produced.

The husks of the grape, after the juice is extracted, become hot when in contact with the air, and all the liquid with which they are impregnated passes to the acid state.

A slight vinegar is also produced with the residue, from the distillation of wines.

In order to clarify vinegar, it is sufficient to throw into a cask of vinegar a glass of boiling milk, and to agitate the mixture; a deposit is formed; the vinegar becomes pale, and preserves its aroma, which it loses upon distillation.

ARTICLE II.

Of the manufacture of vinegar from beer.

Wine vinegar is certainly the best of all. But as this acid forms the base of some important preparations, such as the preparation of sugar of lead, white lead, &c. we have learnt how to make it by the acetification of beer; and the processes which are followed for this purpose are so economical, that numerous white-lead manufactories are established in the North, and supplied with beer vinegar only.

I shall describe the process I have seen practised in the north of France, and I shall conclude with detailing some modifications introduced in this method, in other countries of the north of Europe.

At Gand, in particular, the manufacture appears very perfect : they take,

1440 pounds of malted barley,

540 pounds of wheat,

390 pounds of buck-wheat.

2370*.

These grains are ground, mixed, and thrown into the boiler ; 27 casks of river water are then thrown in ; the whole is boiled for three hours, and there remains 18 casks of good beer, which is drawn off.

They afterwards pour upon the grains, eight casks more water, and boil them again for 16 or 18 hours ; after which the beer is drawn off. This second operation furnishes what is called small beer.

* The pound weight at Gand is, with respect to the Paris pound, as 13 is to 10.

The whole brewing furnishes about 24 casks of beer.

The beer thus prepared by the brewer, is carried to the vinegar-maker, who distributes it in pipes, as they are called, containing nearly three casks. For this purpose, such casks only are employed as have contained Spanish wines or brandies.

These casks or pipes are placed on their sides in a row, upon tressels, which raise them about a foot above the ground. They are placed in an open place, so as that nothing may intercept or weaken the direct rays of the sun. There is a hole in the upper part of each, which measures about six or eight square inches.

Some vinegar-makers ferment the good and the small beer separately, and obtain vinegar of two different qualities, which they afterwards mix together, in order to introduce only one kind into commerce. Others make the mixture of the two kinds of beer before fermentation. It is quite indifferent which method is followed.

The barrels are only filled within half a foot of the aperture. This precaution is absolutely

necessary, that the beer may not run over during the fermentation.

The barrels always continue open ; tiles are placed upon the apertures during night, and in rainy weather.

It is generally towards the end of the month of May that the vinegar-makers are busy, and the vinegar is ready in about four or five months. About the end of September, it is drawn off, in order to be stored.

Every tun of beer contains 140 pots*, which furnish only 120 pots of vinegar ; so that the whole brewing yields 2880 pots of vinegar.

Some vinegar-makers do not make use of any wheat, for which they substitute rye, oats, or garden beans ; but they obtain a vinegar of worse quality. It is ascertained by long experience, that the grains, and the proportions determined as above, yield the best vinegar ; and if we change these proportions, it is always at the expence of the quality of the vinegar.

* The pot-measure at Gand, contains a very little more than an English quart.—T.

On calculating the expence of the operation, at the medium prices of casks, wages, workmanship, outlay of money, the beer produces about two sols the pint.

Every where the grains are fermented for making the beer, but always without any mixture of hops. There are countries in the North, where the acid fermentation is determined by yeasts, the nature of which varies, according to the opinion of the workmen: in some places it is newly baked bread, which is moistened with strong vinegar, and kept some time before using it; in others it is a paste ferment, mixed with jar-raisin stalks, or spoiled grapes, the whole being sprinkled with good vinegar.

In some places the grain is made to germinate, and it is dried in the sun, but not in a kiln, in order to obtain a paler and more agreeable vinegar. It is then bruised when dry, and placed in a tub. Upon 110 pounds of malt, they pour a tun of boiling water, of the size of the tuns which come from Burgundy with wine. After digesting for a quarter of an hour, it is carefully stirred, and allowed to settle for about an hour: the liquor is then

drawn off. The tub has a double bottom, pierced with several holes, and covered with a layer of straw, so that the malt remains above it, and the liquor which passes through, is filtered. The liquor is poured into wooden vessels of several feet broad by one foot high; it is poured out of one vessel into another, and continually stirred with a spatula pierced with holes.

As soon as the liquor has, by cooling, assumed the mild temperature of milk which is about to be curdled, it is poured into large vessels, and beer-yeast is added, to produce the vinous fermentation; 24 hours at least are requisite to produce this fermentation. This beer is then put into casks, which are only three-fourths filled, and the bung-hole is left open. These casks are exposed in a kiln to a constant heat, where their contents are allowed to ferment for about a month or six weeks. The vinegar is clarified by passing it through strainers of felt or woollen.

ARTICLE III.

Of the manufacture of vinegar by the distillation of animal and vegetable substances.

The acetic acid is not only formed by fermentation, as we have seen, but it is also the produce of the distillation of some animal substances, and particularly vegetable substances, which furnish it in large enough quantities to employ it usefully in the arts.

Analysis proved to Messrs. Fourcroy and Vauquelin, that the pyro-mucous, pyro-ligneous, and pyro-tartarous acids, were the acetic acid sullied with a little empyreumatic oil only, and from which it would be sufficient to purify them, in order to have the acetic acid in a very pure state: these two experienced chemists have succeeded in giving to the acetic acid produced from wine, all the characters of these three acids, by dissolving warm, and even in the cold, in the pure acetic acid, the empyreumatic oils of the three substances furnished by these acids.

M. Thenard has proved, on the other hand, that the zoonic acid, which M. Berthollet ob-

tained upon distilling muscular flesh, was only the acetic acid, holding in solution an animal matter, which approaches the oily state.

Thus the acetic acid is daily produced by distillation; and it is the acid, the elements of which, always present in animal and vegetable substances, are combined with the most facility.

The acetic acid obtained by the distillation of vegetable substances, has been already used in the arts to great advantage. But although all the parts of the vegetable furnish this acid, which has been called by various names, according to the particular part submitted to distillation, all of them do not furnish it in the same quantity. The hard woods yield the most, and the process by which they are reduced into charcoal, presents the artist with an economical method of procuring it. It is only necessary to collect, in large receivers well cooled, such as casks plunged two-thirds of their depth in water, the vapours which escape in smoke during the carbonisation; we may direct these vapours by means of iron pipes, similar to those belonging to a stove: this process, which is very economical, fur-

nishes an acid which marks from four to six degrees in the areometer; it is blackish, and exhales an empyreumatic smell; it dissolves iron with facility, and the solution becomes so cold as 20 or 22 degrees of Reaumur.

This acid is preferable to vinegar for the purpose of dyeing and printing on cloth; it carries along with it an oil, which forms an excellent mordant for cotton or linen cloths, and it now supplies the place of the acetic acid in the dye-houses, where it is made use of as the mordant for the blacks, the violets, the lilacs, the nankeens, &c. The colours borne upon these mordants, are better supported, more lively, and much more unalterable than those produced by the common acetate of iron.

The acetic acid, known by the name of *pyro-ligneous acid*, was extracted from wood; the *pyro-mucous acid* was furnished by all the saccharine, or simple mucilages; and the *tartarous acid* by the distillation of tartar.

Independently of these three acids, which have particularly occupied the attention of chemists, it is known that all the vegetable substances, of whatever kind they are, furnish an acid produce, which is of the same nature

with those which we have mentioned. We may therefore lay it down as a principle, that the distillation of the vegetables constantly produces vinegar.

When we wish to employ, for the purposes of dyeing, the acetic acid produced by distillation, it is useless, nay, it would be prejudicial, to deprive it of the oil it holds in solution. But when we want to obtain it very pure, we may attain this object by filtering it through charcoal; it is afterwards saturated with potash, and the acetate is decomposed by distillation.

By whatever method vinegar is obtained, it always undergoes some particular preparations before applying it to use.

Vinegar always contains a more or less considerable quantity of extractive principle, of which it must be cleared by distillation: without this precaution, it would bring with it into its combinations a foreign principle, which would not only alter the quality of the product, but would retard the action of the acid upon the bodies with which it was combined.

The distillation may be effected in glass utensils, when we wish to prepare a small

quantity only ; and in copper alembics when the vinegar is prepared for sale.

The distillation begins at the boiling point ; but the first that comes over is weak, and the most concentrated acid always comes last.

Distilled vinegar is as clear as spring-water : it is more energetic than that which has not been distilled.

One inconvenience attending distilled vinegar is, that it is a long time in losing its fiery smell ; but this inconvenience is only felt when we use it at table. Besides, we may guard against this flavour by distilling it in B. M. and by thickening the water of the bath by a strong solution of any salt, such as the muriates and nitrates of lime, or the mother-waters of any salt, in order that the water itself may assume a heat higher than that of boiling water.

Two kinds of vinegar are known in commerce : white vinegar, which is made with white wine or with red wine, made sour over the husks of white grapes ; and red vinegar, which is produced by the acetification of red wine.

Vinegar is susceptible of dissolving and preserving the odoriferous principle of vegetables : we may therefore *aromatize* it : and this art, so simple in its principles, has become a considerable branch of industry. Lavender, thyme, citron, &c. are the substances over which vinegar is generally distilled, in order to imbibe their odour. The most of these vinegars are prepared by infusion ; they are afterwards filtered with the greatest care, in order to separate all the foreign principles which might alter their colour or quality. We may also aromatize vinegar by the mixture of the aroma of the plants separately extracted. The name of *compound vinegar* is generally given to that infused over vegetables. Medicine, and the art of perfumery, have seized upon these methods, in order to furnish an agreeable vehicle for medicaments or perfumes.

Vinegar is employed, in order to preserve victuals, fruits, and leguminous substances. M. Parmentier observes on this subject, that it displaces the water with which these substances are penetrated, and unites with the principles which compose them, particularly with the gelatine.

A syrup is made with vinegar, which furnishes a beverage as wholesome as it is agreeable.

Some people are in the habit of concentrating vinegar by freezing it: by this means it is separated from a part of the aqueous principle, which is converted into icicles, which they take off as fast as they are formed.

But when we wish to obtain a still purer and better dephlegmated vinegar, we distil the products into which it enters as a constituent principle, such as the acetate of copper, or crystallized verdigris, and the acetate of potash, strongly thickened, as directed by Stahl. Vestendorf has suggested the distillation of the acetate of potash, with half its weight of sulphuric acid, in order to obtain a highly concentrated acid.

Lowitz perfected this process, by distilling three parts of acetate of potash with four parts of sulphuric acid. He afterwards redistilled the produce of the first distillation, over the acetate of barytes, which retains any sulphuric acid it may contain. The acetic acid is then so much condensed, that it is reduced into the form of crystals.

It remains to say a word of the modifications presented by this acid in the various states in which it is found, and of the circumstances which favour its formation.

An experiment which I made in 1781, and which is to be found in the Memoirs of the Academy of Sciences of Paris, for the year 1786, may throw some light upon the formation of the acetic acid *.

We place immediately upon the head of the vessels containing the produce of the vintage in fermentation, shallow vessels, filled with clear water: after three or four days, the water becomes acid, and it is put into bottles, which are deposited in a quiet place, where the temperature is about 20 degrees of Reaumur. The bottles are left uncorked: at the end of a month, sometimes sooner, but often later, flakes are liberated from the heart of the liquor; a slight fermentation is excited; the liquor assumes the taste and smell of vinegar; the flakes are deposited; the liquid clears up, and the vinegar is made.

* This experiment constantly gives the same results, when we operate upon very generous wines, such as those of the South.

It must be observed, that if, in place of employing pure water, we make use of pump water, or any other holding an earthy sulphate in solution, the phenomena are not the same. The sulphuric acid undergoes a decomposition, which is known by a smell of sulphuretted hydrogen gas, and by the sulphur which is precipitated in a native state.

It is beyond a doubt, that in this experiment the formation of the vinegar is owing to the action and decomposition of alcohol dissolved in the water, and of a portion of extractive principle which it carries with it. The existence of these two principles is demonstrated by analysis. The smell of alcohol, which is perceived around a vessel in which the fermentation is going on, may make us easily conceive how it is possible that water placed upon the vessel, becomes impregnated with it : the existence of the extractive matter is less easy to conceive ; nevertheless, it is real, and we cannot refuse admitting, that this substance has been carried along with the alcohol or the carbonic acid.

In this experiment of acetification, the sulphuretted hydrogen gas produced in one cir-

constance, shews that water, as well as sulphuric acid, is decomposed in order to furnish oxygen.

The following experiments, which present as a result the formation of acetic acid, throw more light on the nature of this product.

Scheele obtained vinegar upon treating sugar and gum with oxyde of manganese and nitric acid.

The same chemist observed, that the last results of the decomposition of acids over alcohol in the formation of ethers, were acetic acid.

He also saw that oxalic acid, over which nitric acid was decomposed, was transformed into vinegar. Hermstadt made the same observation with regard to the tartarous acid.

Scheele caused the gallic acid to pass to the state of acetic acid, by means of the nitric acid.

Creel, upon boiling alcohol with sulphuric acid and manganese, obtained vinegar and azotic gas.

When we digest for some months a mixture of alcohol and oxalic acid, the whole becomes vinegar.

On mixing nitric acid with alcohol, we obtain at pleasure, either oxalic or nitric acid. The latter requires a stronger dose of nitric acid than the former.

M. Berthollet announced, in 1785, that the oxy-muriatic acid could convert alcohol into sugar, vinegar, and water, by abandoning its oxygen.

The sap of trees presents acetic acid; after some hours repose in vessels. The bark yields it when heated. Water in which we soak the leguminous substances, cabbages, carrots, turnips, potatoes, cucumbers, &c. is strongly acetous.

Scheele extracted it from sour milk; Messrs. Fourcroy and Vauquelin, found it in broths or animal jellies, as well as in the urine of the mammiferous class of animals.

It results from the numerous experiments hitherto made upon this acid, that it is the produce of fermentation, of distillation, and of the decomposition of the nitric and oxy-muriatic acids over vegetable matters, or over other acids extracted from these substances.

From all which it follows, that the radical of this acid is throughout all the vegetable

kingdom; that any circumstance which presents oxygen to a vegetable, forms this acid, which seems to be composed of hydrogen, carbon, and oxygen, in proportions of which we are as yet ignorant.

The hydrogen and the carbon exist in alcohol, and in the extractive principle of vegetables; but hydrogen predominates in the former, and carbon in the latter; so that if we oxygenate them separately, alcohol would furnish plenty of water, and very little acetic acid. The extractive would furnish plenty of carbonic acid, and a little acetic acid. But when the two principles are united, and they are oxygenated by any process whatever, water and carbonic acid are then produced, which bring the two principles into the proportions proper for forming the acetic acid.

The distillation of the acetate of copper (crystals of Venus, crystallized verdigris), yields a very pungent acetic acid, and so much concentrated, that the last which comes over in the operation, burns the skin, as observed by M. Bonvoisin (Memoirs of the Royal Academy of Turin, 1788 and 1789).

It has been thought, that this acid differs from common vinegar; I have even proved,

that it contains much less carbon ; but M. Darracq has made it appear, that this excess of carbon is occasioned by the extractive which is mixed with the vinegar ; and that when it is cleared of it, these two states of the acid only differ in the degree of concentration.

There is only one acid of vinegar, therefore, known at present, which is called *acetic acid*.

SECTION XIII.

Of the oxalic acid.

We are indebted to the celebrated Bergman for the discovery of this acid. He published it on the 13th of June, 1776, in a thesis he sustained at Upsal.

This acid was at first known by the name of *acid of sugar*, *saccharine acid* ; and it has been regarded as a modification of the nitric acid, because we obtain it by the action of this acid upon sugar.

At present, this acid is called the *oxalic acid*, because it is ascertained, that it is the same acid which is in combination with potash in the salt of sorrel.

The process detailed to us by Bergman for

forming or extracting this acid, is confined to the following :

We place in a tubulated retort in the sand-bath, one part of pounded sugar, and three parts of common nitric acid, the specific gravity of which is, to that of water, as 1.560 : 1.000. The sugar soon dissolves, red vapours are immediately thrown up, and the mixture effervesces with great violence. As soon as the effervescence ceases, the fire is lighted, and the liquor soon becomes brown. We then pour in a similar quantity of nitric acid, and the boiling is continued.

When the liquor is sufficiently thick (which may be judged of from some small crystals that are formed at the surface, or by cooling a small quantity), it is poured into a capsule ; four-sided, long, and narrow prismatic crystals are formed.

The mother water is replaced in the retort, and a new quantity of nitric acid is poured upon it. We then evaporate as at first, and we obtain a second quantity of crystals.

By following this process, plenty of malic acid is formed ; and towards the end of the operation, carbonic acid only is produced.

I found it much more advantageous to employ nine parts of nitric acid to one of sugar; the decomposition of the nitric acid is more complete, and the produce in oxalic acid is more considerable.

After the first quantity of crystals, when the *mother waters* are again put upon the fire, I also add a third of the whole of the sugar previously employed: a new quantity of nitrous gas is liberated, which becomes red, and I obtain a new quantity of crystals.

I evaporate the mother waters again, and add sugar or acid, whichever of them is wanted.

But the first crystals are covered with nitric acid, of which they must be cleared by successive solutions in water, and subsequent crystallizations. If the ebullition is strong, there is a considerable waste, because this acid volatilizes to such a degree, that when the evaporation is made in the sand-bath in open vessels, it is difficult to continue near the place, in consequence of the fretting of the skin, and the sneezing these emanations occasion.

The regular form of well-purified crystals of

oxalic acid, is that of a prism with four faces, terminated by dihedral summits.

Sugar is not the only substance which furnishes the radical of this acid: Bergman extracted it from gum-arabic, in the proportion of about a quarter of the weight of the gum employed. Alcohol, treated with thrice its weight of nitric acid, furnished the oxalic acid in the proportion of three-eighths of its weight.

Two ounces of manna, treated with twelve ounces of nitric acid, at 32 degrees, furnished me with 2 drachms 66 grains of oxalic acid.

One ounce six drachms of extract of wheat-flour, upon which I decomposed 16 ounces of nitric acid, at 36 degrees, yielded me 4 drachms 36 grains of oxalic acid.

The extract of rye-flour furnished me with one-third at least, and that of barley-flour with a fourth less than the latter, although it was far sweeter to the taste.

Two ounces of extract produced from one pound of white beet-roots, treated with eight ounces of acid, at 41 degrees, yielded three drachms four grains of oxalic acid.

One ounce of extract of parsnip-root, and eight ounces of nitric acid, at 41 degrees, yielded 36 grains of oxalic acid.

The extract of dry raisins yields one-eighth of the acid in question : that of maples, 1 drachm 22 grains in the ounce ; and that of the ash-tree of our southern climate, nearly two drachms.

Eight ounces of nitric acid, at 40 degrees, furnished 2 drachms 36 grains for each ounce of gum-arabic : gum-adracanth gave less.

M. Berthollet extracted this acid in a small quantity from cotton, and in a greater or smaller quantity from silk, woollen, leather, cartilages, hairs, gelatine, albumen, yolks of eggs, gluten, &c.

Hermstadt proved, that we may bring to the state of oxalic acid, by the decomposition of the nitric acid, the acids of the tamarind, citron, prune juice, pears, gooseberries, prickly sorrel, sorrel, &c.

Scheele converted the gallic acid into oxalic acid by the nitric.

We may therefore regard the oxalic acid as having for its base a radical, which exists in almost all the vegetable and animal substances,

and which only requires oxygen to pass it to the acid state. The facility with which these acids are converted into each other, by giving them more or less oxygen, and by taking from them more or less carbon or hydrogen, does not admit of a doubt that all of them have a common radical, which varies afterwards in its proportions with the oxygen, and by that of the two radicals among themselves.

The oxalic acid has been found in a free state in the down of chick pease : we are indebted for this beautiful observation to Messrs. Deyeux and Proust.

The oxalic acid has all the characteristic properties of the acids : its taste is very strong : it only requires seven grains in order to acidulate very sensibly a pint of water : only one part dissolved in 1020 parts of water, reddens blue sugar-paper ; and one part dissolved in 3600 of water, colours in red the diluted blue colour of turnsole.

This acid is very soluble in water, and produces a very sensible cold in that liquid. Boiling water dissolves an equal weight of it ; cold water dissolves one half of it, when it is at the temperature of 12 degrees of Reaumur.

100 parts of boiling alcohol take up 56 of acid.

The crystals of oxalic acid lose by heat, three-tenths of the water of crystallization.

The properties which essentially characterize the oxalic acid, viz. those upon which the uses to which it is applied are founded, are, 1. the faculty of taking up lime from the principal known acids; 2. the facility with which it dissolves the oxyde of iron.

The first of these processes renders it valuable as a re-agent, in order to ascertain and establish the presence of a calcareous salt held in solution in any liquid. But the oxalate of ammonia also presents a more active re-agent than the non-combined acid: a small crystal of oxalate suspended on the surface of common water, and in contact with it, presents, a single moment afterwards, a white cloud immediately under it, which already announces the decomposition of the earthy salt; and when we precipitate the crystal of oxalate through water, it leaves behind it a cloud, which marks the line it has followed, and the successive and rapid decomposition which has taken place.

But it is particularly by the property which the oxalic acid has of dissolving the metallic oxides, that it is valuable in the arts. Already, in the manufactories of printed cloths, it is in considerable demand, for taking out the mordant from above some parts of the stuffs. In place of giving the mordant with a plate, and tracing by this means a drawing on it, all the cloth is covered with mordant; and when it is dry, this acid is applied, suitably gummed, upon the parts which are wanted to be kept white; the acid destroys the mordant, so that the colour will not take any longer on the place where the mordant had been applied. It is by this method that all the delicate designs are executed, which could not be done with the plate.

We may easily conceive that if, by means of this acid, we may completely take the mordant from off some points of the cloth, for a much stronger reason we may correct and modify the energy of it, so as to produce all kinds of shades upon any piece of cloth wholly impregnated with mordant: it is only necessary to vary the strength of the acid, which is employed in a secondary manner.

The oxalic acid is the most proper substance that can be employed for taking out the stains of ink from clothes, linen, &c. : it is only requisite to bruise a small crystal of it upon the spot, previously moistened with water, and to rub it with the linen itself, in order to produce the solution. We may also use a strong solution of this acid in water.

SECTION XIV.

Of the benzoic acid.

The balsams are resins, naturally united to an odoriferous and concrete acid. Natural history presents three principal balsams : *benzoin*, *balsam of Peru*, and *storax calamite*.

We may extract a concrete acid from each of these three balsams ; but scarcely any one of them is employed for this purpose, except the *benzoin*, and the acid then bears the name of *benzoic acid*.

We are acquainted with two varieties of *benzoin* in commerce ; the *amygdaloidal*, and the common *benzoin*. The first is formed by the finest tears of this balsam, tied together by a

gluten or juice of the same nature, but browner. The other kind of benzoin is the juice itself, without any mixture of those fine tears.

Benzoin, when put upon the fire, melts, hastily inflames, and, when burning, gives out a strong aromatic smell. But if we heat it without inflaming it, it swells, and emits a sweeter smell, although very strong.

Benzoin, bruised and boiled with water, furnishes a very soluble salt, which crystallizes, on cooling, in long needles. But by this method we cannot extract the whole of the acid salt contained in the benzoin, because the resin, impenetrable to water, protects a portion of it from the action of this solvent.

Recourse has been had to sublimation for separating the salt from the resin: to this effect, the benzoin, when pounded, is put into a glass matrass, which is placed in a sand-bath, and we proceed to the sublimation by a gradual heat; the acid salt is separated from the mass, and is deposited in very white long needles, in the capacity of the vessel.

Some chemists put the benzoin into a common plate, cover it with another one, and lute the joinings with paper: they make a

small aperture towards the middle of the upper plate, and place the apparatus on the fire. The heat volatilizes the acid salt, which is separated after the vessels are cooled, by unluting the two plates.

These processes do not furnish all the salt contained in benzoin : a great part escapes in vapours ; this salt is therefore very high priced.

In order to obtain it in the greatest quantity, I begin by distilling the benzoin in a retort, and bring over into the receiver all the balsam ; I boil water upon the disorganized produce, and then easily separate all the salt, which is precipitated by cooling and evaporation.

Scheele proposed to extract the benzoic acid by lime-water : he decomposes the benzoate, which is produced by it, by means of the muriatic acid ; and separates the acid, by crystallizing it in the solution of muriate of lime.

The benzoic acid becomes brown after some time : it is even very rare to obtain it very white, when it is extracted by means of water ; this is owing to a portion of oil, which is almost inseparable from it, but from which it may be freed, however, by mixing it with

charcoal, and subliming it afterwards by the application of a sufficient heat.

The benzoic acid, sublimed, or reduced into vapours by the fire, has a very penetrating aromatic smell, which excites coughing: it is prudent not to open the vessels in which it is sublimed until they are cold; without this precaution, we might lose a part of the salt, and be exposed to these irritating vapours.

This acid salt reddens blue paper.

It liberates the acid from carbonates, and perfectly combines with the metallic, earthy, and alkaline bases.

Benzoic acid has been found in the urine of animals which live upon fruits: Messrs. Dey-eux and Vauquelin, in 1792, observed, that the concretions deposited by cinnamon-water, have the properties of the benzoic acid; and Scheele was struck with the analogy he perceived between the acid salt sublimed from gall-nuts, and the benzoic acid.

SECTION XV.

Of the prussic acid.

It was formerly thought, that the prussic acid belonged exclusively to animal substances; but M. Schrader, a chemist in Berlin, and M. Vauquelin, obtained it by the distillation in B. M. of bitter almonds bruised, and leaves of peach-trees. M. Vauquelin has also extracted it from nuts and apricots; and it is probable that the leaves, the flowers, and the fruits of the peach-tree, as well as the kernels of plumbs and cherries, contain it also, since there is a striking analogy in the smell of these substances.

But animal substances have been the only ones hitherto employed for extracting the prussic acid used in the arts; and although the distillation of blood, and the action of the nitric acid upon animal albumen, gluten, and fibres produce it, it has been chiefly by presenting to it an alkaline base, that it has been hitherto extracted: and it is afterwards from these new combinations that we liberate it.

it is only decomposable after a long digestion with other metallic substances.

This solution is poured into a flask, containing half an ounce of iron-filings, not oxidated, adding three drachms of sulphuric acid, and it is shaken for a few minutes : the mixture becomes totally black, in consequence of the reduction of the mercury. The liquor loses its mercurial taste, and assumes that of peach-flowers. This very volatile prussic acid is separated by distillation in a gentle fire.

Scheele advises that the apparatus should be well luted, and that a little water should be put into the recipient ; and also that small vessels should be employed, in order to lose the least possible quantity of acid, and to facilitate the condensation by means of a cold temperature.

The prussic acid has peculiar characters which serve to distinguish it from all others : 1st, its smell is analogous to that of bitter almonds ; 2d, its taste becomes mild, and produces heat in the mouth, provoking a cough ; 3d, it takes oil from all the acids, and forms a blue prussiate ; 4th, it precipitates oil and sulphur from their combinations

with alkali ; 5th, it is very volatile, very elastic, and is not decomposed by heat.

M. Berthollet, who has studied this acid with the eye of an observer, who embraces and enlightens every thing, concludes from his own experiments, that it is a compound of hydrogen, carbon, and azot. The simple distillation of various alkaline or earthy prussiates, support this opinion : that process only produces hydrogen gas, azotic gas, ammonia, and a little carbon.

If the distillation of the metallic prussiates furnishes carbonic acid, according to the observations of Scheele, it is because the metals being in the state of oxydes, furnish the oxygen necessary to the formation of the carbonic acid.

M. Fourcroy, who extracted, by distillation, from 10 parts of the *serum* of the blood, and one part of nitric acids, azotic gas, nitrous gas, prussic, and carbonic acid gases, concluded from this circumstance, that the prussic also contained oxygen, which it takes from the nitric acid, since the *serum* of the blood, when distilled by itself, does not furnish prussic acid : M. Berthollet answered, that the action of

the nitric acid also separated ammonia in some circumstances, and that nevertheless we cannot conclude from this, that it contains oxygen. It seems to me also, that in the experiment of M. Fourcroy, the carbonic acid may have been formed by the oxygen of the nitric acid, and that the prussic acid may be free from it: besides—the property possessed by pure prussic acid, of reddening the oxydes of iron, copper, mercury, and silver; the faculty possessed by the metallic prussiates, of furnishing, upon distillation, carbonic acid, while the alkaline prussiates furnish none at all; the necessity of presenting to the prussiate of mercury, a body which may seize upon the oxygen of the oxyde, in order to set free the prussic acid;—all these, I say, are phenomena that do not seem to agree with the existence of oxygen in this acid.

The manner in which the oxy-muriatic acid modifies the prussic acid, also furnishes proofs of the non-existence of oxygen in this acid. If we mix these two acids, the former becomes once more common muriatic acid, and the latter assumes a brisker smell, and much more volatility, at the same time that its affinity for lime and the alkalis is weakened. In this

state it precipitates iron in green, and this green does not become blue, except when by the action of light or of sulphurous acid, we displace or seize upon the oxygen thrown down by the oxy-muriatic acid.

Prussic acid impregnated with oxy-muriatic acid, and exposed to the light, assumes a smell of aromatic oil, and collects at the bottom of the water into a small quantity of an oil not inflammable, and which is evaporable on the application of a slight degree of heat. By repeating the experiment, we may decompose the prussic acid completely, and then this kind of oil becomes concrete, and is reduced into crystals. Iron, and the sulphurous acid, do not restore it.

The prussic acid, saturated with oxygen, and mixed with lime or potash, disengages ammonia, and carbonic acid is formed, which unites with the potash or the lime.

The decomposition of the prussic acid by oxygen, furnishes us therefore with carbonic acid and ammonia; and every thing inclines us to think, that oxygen cannot be regarded as one of its elements.

SECTION XVI.

Of the gallic acid.

The decoction of gall-nuts reddens blue paper, turnsole tincture, and that of mallows and small radishes : these facts were known ; but no chemist, before Scheele, extracted this acid, in order to ascertain its particular properties.

This celebrated chemist advises us to infuse the powder of gall-nuts in water, and to stir it for four or five days, while the infusion continues : the liquor is afterwards filtered, and it is exposed to the air in a bell-glass, until a considerable precipitate is formed : this precipitate is washed with cold water, it is then dissolved in warm water, filtered, and evaporated at a gentle heat. During the evaporation, one part is precipitated like fine sand, while the other part forms at the bottom, crystals in the form of a sun. This acid salt is grey, and it is impossible to render it whiter by repeated solutions, filtrations, and crystallizations.

The same chemist also extracted from gall-nuts, by distillation, an acid phlegm, and ob-

served, that towards the end of the operation, a volatile acid salt arose; he recognized in this sublimed salt, the smell and taste of benzoic acid.

M. Deyeux afterwards proved, that a heat a little higher than that of boiling-water, was sufficient in order to sublime the acid salt to the neck of the retort, where the distillation was going on.

M. Proust, who also turned his attention to this subject, has pointed out to us a method of obtaining this acid very pure: it consists in pouring solution of nitro-muriate of tin upon a decoction of gall-nuts; there is almost immediately formed a very abundant yellowish precipitate, and the liquor which floats above, contains gallic acid, muriatic acid, and muriate of tin; the precipitate is a combination of tannin, with the oxyde of tin.

Sulphuretted hydrogen gas is passed through the solution, in order to precipitate the tin which remains in it; the liquor is allowed to settle a few days; it is filtered and evaporated in a glass capsule, until the gallic acid crystallizes upon cooling.

M. Berthollet proved, that we might obtain

this acid by leaving the infusion of gall-nuts in close vessels, from which the air was totally excluded. This celebrated chemist tried in vain to extract a similar acid from shumac, from the green shells of walnuts, and several other astringents: it seems that it is only contained in gall-nuts; and it gives them properties which no astringent possesses in the same degree.

This acid has a sour taste, like all the others, and reddens the blue vegetable colours, which are generally used as tests for it.

It dissolves in three parts of boiling-water, and is precipitated in crystals by cooling.

Boiling alcohol dissolves it in equal weight. This acid precipitates gold, in a green colour, from its solutions; silver, in a brown colour; mercury, in orange yellow; copper, in brown; iron, in black; lead, in white; bismuth, in citron yellow.

Platina, zinc, tin, cobalt, manganese, experience no change from it.

This acid salt is decomposed by repeated sublimations.



We have now finished all we had to say on the subject of the acids: there are others in existence, which we shall have occasion to mention when we come to the oxydation of the metals. But we shall pass over many of them in silence; in the first place, because they are of no use; and, secondly, as being the produce of a distillation, or the result of the decomposition of the nitric acid over a vegetable or animal substance, they may be multiplied, *ad infinitum*, in consequence of innumerable varieties in the proportions between the oxygen and the radicals, or between the radicals themselves.

TITLE III.

OF THE MIXTURE AND COMBINATIONS OF
BODIES WITH EACH OTHER.

HITHERTO we have considered bodies in their simple state, or under their form of elementary principles: it was the only method to fix their properties, which it is necessary to know, in order to follow the effects of combinations, and to analyse the results of all the decompositions which we daily witness. If we have comprised the acids within the class of simple bodies, although the most of them are evidently compounds, it is because these substances are very susceptible of forming combinations, serving us as agents or intermedia, in almost all our operations; and because it is almost impossible to proceed by analysis or synthesis, without employing the acids.

CHAPTER I.

Of the mixture of the gases with each other.

SECTION I.

Of the mixture of oxygen gas with azotic gas (terrestrial atmosphere or atmospheric air).

The atmospheric air is that mass of fluid in which we move and breathe.

At all times it has been an object of study among naturalists; but all their researches have ended in merely making us acquainted with some of its physical properties. It was reserved for modern chemistry, to ascertain the nature of it—to demonstrate its principles—and to determine its uses—by the analysis and the results of its formations and decomposition.

The chemist ought to consider the atmosphere in four respects: 1st, in its action upon the other elastic fluids; 2d, in respect of the influence of its weight upon chemical operations; 3d, in the nature and proportions of its constituent principles; 4th, in the com-

bination of its principles with other substances.

1st, Not only have the gaseous fluids a very remarkable action upon solids and liquids; but they also act very powerfully among each other. Mr. Cavendish (*Experiments upon Air*, *Philosophical Transactions*, 1784), observed, that on agitating a mixture of 10 parts of atmospheric air and one of carbonic acid, with an equal volume of distilled water, the latter only took up from the air one half of the carbonic acid: an equal quantity of water, treated in the same manner, only takes up the half of what remains of the carbonic acid, &c. M. Berthollet has found, that if, in the combustion of a carbonated hydrogen gas, there is a residue, the latter retains nearly one-tenth of the carbonic acid formed, although we agitate it over a very considerable quantity of water. It is in consequence of the action which the air exercises upon carbonic acid, that it takes up from the water that which may be there in solution. All the eudiometrical processes by which we endeavour to extract all the oxygen gas contained in a given quantity of atmospheric air, in order to determine its proportions,

cannot succeed in separating it completely. Messrs. Vassali and Volta remarked, that the hydrogen and carbonic acid gases, gradually mix with the atmospheric air, so as to spread through it equally. M. Volta even observed, that by virtue of this dissolving action, the hydrogen gas descended into the atmospheric air, in order to mingle with it *.

This affinity among the gases, also explains why the air floating in the atmosphere at 4000 fathoms above the earth, presented to M. Gay-Lussac the same proportion among its constituent principles, with the air at the surface of the earth.

All this proves, that in the mixture of the gases, there takes place a kind of saturation; and that when the respective gravities vary little, like those which exist between azot and

* This ought to allay the fears of those who believe that the hydrogen gas which is liberated in consequence of the decomposition of bodies, constantly rises into the upper part of the atmosphere, in order to form a particular stratum, and that it will finally exhaust the surface of the globe of one of the constituent principles of bodies.

oxygen, we find their mixture in very nearly the same proportions, at all heights.

The difference that exists between the mixtures of liquids and those of gases, is this : in the former, there is a condensation, a change of temperature and volume ; while in the mutual action of the gases, none of these phenomena are observed, provided there is no combination.

The combination of the gases ought to be well distinguished from their mixture. Combination produces condensation, and gives birth to new properties. Mixture does not change the individual properties of the gases ; they are only feebly diminished, or modified, in proportion to the affinity which connects them. Mixture establishes a permanent state of a gas which has particular properties, different from those of the bodies which constitute the mixture, nevertheless without there being any combination.

There are combinations of some gases among each other, which bring back to the earth the substances which, by successive decompositions, had been elevated from it. Ammonia is there

combined with carbonic acid, and the atmosphere which makes up the gaseous fluids that escape from our earth, soon returns them in a state of combination.

We have already said, that vapours were only liquids dissolved in caloric, and capable of being precipitated from it by abandoning the dissolvent, or by their combinations with other bodies. It is important to examine all these phenomena, particularly with respect to water, in consequence of the great share it has in all the operations of nature and art.

If the temperature is higher than that which is necessary to keep a liquid at the boiling point, the liquid remains in a permanent state of vapour; and it acts like the other gaseous fluids, as M. Gay-Lussac has proved.

When the temperature of a liquid is raised to, and kept at the boiling point, if we diminish the compression, the vapour dilates like any other gas; if we increase it, it precipitates a portion of the liquid, until the pressure corresponds to that of 28 inches of mercury, or to that of the atmosphere.

The water which is dissolved in the air, takes the elastic state in it: M. Deluc has

already observed, that the humid air was lighter than the dry, and has thereby explained the lowering of the mercury in the barometer in a humid atmosphere.

Leroy, a celebrated physician at Montpellier, has announced, that water is dissolved in the air, and he compared this solution to that of a salt in a liquid. M. de Saussure has modified this doctrine, and has proved that the volume of the air is affected by it, according to its compression and temperature; and that at a temperature of 15 degrees (Reaumur), a cubic foot of air only holds in solution 11 grains of water, and this quantity diminishes on lowering the temperature. This celebrated naturalist has also proved, that the quantity of aqueous vapour, in point of weight, is constantly the same in the same space, whatever is the quantity of air; and that the temperature alone, makes this quantity vary.

It follows from the experiments hitherto made by Messrs. Saussure, Deluc, Volta, Berthollet, &c. 1st, that the air dissolves the evaporable liquids, in consequence of its affinity; 2d, that in this solution, they assume the form of elastic fluids; 3d, that in this state, they

possess all the properties which belong to fluids.

It follows from all this, that water held in solution by the air, acquires, in consequence of the elastic state the latter gives it, the same properties it has when reduced into vapour by means of heat.

The air has the property therefore, of maintaining water in an elastic state, and of giving it the properties of a permanent gas, until the term of its saturation.

These principles are applicable to all solutions, of any liquids whatever, in the gaseous fluids.

It also follows from the above, that the elastic vapour of water experiences, by the variation of temperature above that of ebullition, the same dilatation as the other gases.

M. Saussure proved, on comparing the quantities of water he dissolved in the dry air, and the increase of tension resulting from it, that there was a constant reference between the vapour produced and the tension; and that the weight of this vapour was to that of the air, as 10 to 14, at an equality of temperature

and compression. But Lavoisier concluded from his experiments, that the specific gravity of the air at 10 degrees (Reaumur) was to that of water as 842 to 1, which, on calculating at one-third, the augmentation in volume of the vapour of water, from 10 degrees of Reaumur's thermometer up to 80, gives a specific gravity of 1570.

The liquids which pass to the state of vapour, carry along with them, almost always, a portion of the substances they hold in solution. This is particularly observable in the manufactories where they evaporate solutions of metallic salts, in order to crystallize them. It is a consequence of the affinity of the dissolvents for the salts; an affinity sufficiently strong to overcome the resistance which the gravity of the saline substances presents.

2d, Having already treated of the modifications produced by the elasticity of the atmosphere upon the laws of affinities, we shall only say a word or two upon the influence of its weight in chemical operations.

When we diminish the weight of the atmosphere, not only the gases are dissolved in a

lesser quantity in the liquids, but even those which were dissolved in them, make their escape.

All the causes which increase the elasticity of a gas, diminish its tendency to combination : this elasticity increases by means of caloric, or by the diminution of the weight of the atmosphere.

We may therefore consider the weight of the atmosphere as a cause always acting, which resists volatilization, and retains in solution, or in a state of combination, or even in the liquid state, those bodies which are endowed with an elasticity sufficient for appearing in the form of gas, as soon as its compression diminishes ; so that if we could suppose for a moment, that the atmosphere should ever cease to compress with its weight, the bodies at the surface of our globe, we should see almost the whole of the gases dissolved in liquids escape from them ; the most of the combinations disunited ; and several liquids evaporate, and preserve the permanent state of vapours.

Chemists and naturalists have endeavoured to take advantage of this property of the atmosphere, in order to vary its action upon

bodies: they increase or diminish the solvent virtue of liquids; evaporate or condense these same liquids, almost at pleasure, by modifying the pressure of the atmosphere: and this physical force has become all at once one of the grand agents in the hands of the naturalist, and one of the principal resources of the chemist.

Messrs. Laplace and Lavoisier have made important observations upon the evaporation of ether and alcohol in vacuum; they have thence concluded, that the elastic form of vapour increases according to the temperature, and that the fluid passes to the gaseous state at the moment that its tension becomes stronger than the pressure of the atmosphere.

3d, The atmospheric air is composed of two gaseous fluids; oxygen gas and azotic gas, which form with each other that kind of combination called by M. Berthollet *solution*, in the elastic fluids, and which preserve in this state the dimensions proper to each species of gas.

It was in 1774 that the celebrated Lavoisier demonstrated, by a direct experiment, that tin, kept in a state of fusion in close vessels filled

with common air, became partly oxydated; that it increased in weight; that the air which remained in the vessels was no longer fit for causing combustion; that there was an absorption of a part of the air contained in the vessels; and that the increase in the weight of the metal, was in proportion to the weight of the air absorbed.

After Lavoisier, Priestley calcined tin, lead, and iron, in vessels closed by means of a strong tile; and he constantly remarked, that the air of the vessels diminished about one-fourth, and that when the air suffered no diminution, the metal underwent no alteration.

If we expose a determinate quantity of mercury to a gentle heat, in contact with a known quantity of air, which is carefully renewed, in order to keep up the oxydation of the metal, the mercury will first assume a grey, and then a red colour; it will sensibly increase in weight, and this increase will answer very exactly to the quantity of air that has been absorbed. If we distil the mercury thus altered, and collect the gaseous products of it in the hydro-pneumatic apparatus, we shall obtain a volume of

gas equal to that which has been absorbed, and the mercury will re-appear under its primitive form. The air which is produced by this distillation, is more proper for combustion and respiration than the atmospheric air : when mixed with that which remains in the vessels where the mercury had been calcined, it restores to the latter all the properties of atmospheric air it had lost.

All the metals may be burnt by the electrical spark ; and in all these cases, there is an absorption of a portion of air, and a proportional augmentation of weight in the metal. M. Van Marum has proved, that the electrical spark only calcined the metals in an atmosphere containing oxygen.

If we burn phosphorus in a determinate volume of air, the produce of the combustion is acid ; it weighs more than the phosphorus employed ; there is an absorption of a portion of air, and the residue is improper for combustion.

The same results are observed in the combustion of sulphur, charcoal, and oils ; but in these last cases, the produce of the combustion

evaporates ; and the combination of a portion of air with the body burnt, although equally real, is not so evident.

An inflamed body, placed in a bell-glass filled with common air, and the edges of which are inserted into the water of a tub, at first dilates the air of the vessel ; but gradually, the flame decreases, and is extinguished ; and the water rises, in order to occupy the vacuum as it is formed.

Animals have also the faculty of altering the air by respiration, and absorbing a part of it.

Thus, in an infinite number of cases, the atmospheric air is decomposed, and separated into two principal elements, one of which has been successively called *air of fire*, *vital air*, *oxygen gas*, and *dephlogisticated air* ; and the other, *azotic gas*, *nitrogen gas*, and *alkaline gas*.

The first element is eminently proper for respiration and combustion : hence the denomination of *air of fire*, or *vital air*. It is the acidifying principle of almost all the acids, which has caused it to be called *oxygen*.

The second element is neither proper for combustion or respiration : it forms the base

of nitric acid and ammonia : hence the origin of the denomination by which it is known.

As it is important to be able to appreciate, in many circumstances, the proportions in which the two gases are found in the composition of the atmosphere, great efforts have been made to extract, by simple and rigorous methods, all the oxygen gas ; and it is this science which constitutes *eudiometry*.

There are two kinds of eudiometers employed : by the one, we mix with a determinate volume of atmospheric air, a gaseous substance, capable of forming with oxygen a production fixed or soluble in water ; the proportion of the oxygen gas is concluded by the diminution of the volume of air acted upon. This way of analyzing the atmospheric air, constitutes essentially M. Volta's method, which consists in mixing a certain quantity of hydrogen gas with a determinate volume of atmospheric air : the mixture is inflamed by the electrical spark ; water is formed : the diminution of the volume gives the proportion of oxygen.

In the second kind of eudiometer, we combine the oxygen with a simple combustible

body, and in a concrete state; and we judge of the proportion of the oxygen, 1st, by the diminution of the air employed; 2d, by the weight of the compound produced.

The nitrous gas, employed successively by almost every chemist since the days of Priestley, who first made it known, forms an eudiometrical method of the first kind. Its effect is founded upon the circumstance of the nitrous gas passing to the state of nitric acid in taking up oxygen; so that upon mixing, in tubes above water, a determinate volume of atmospheric air and of nitrous gas, the acid is formed, which is dissolved in water; all the oxygen is employed in this conversion, and the azotic gas only remains. But Fontana, and particularly Ingenhouz, have observed great variations in the results, according to the agitation, the temperature, the proportion, the dimensions of the apparatus, the qualities of the water, &c. Mr. Cavendish has obviated one part of these inconveniences, by causing the nitrous gas to pass into the air bubble by bubble; but it results from the observations of this great philosopher, that it is almost impossible to obtain comparative results. M.

Humboldt was of opinion, that the nitrous gases only differed from each other by the proportions of a quantity, more or less considerable, of free azotic gas ; and he proposed to determine it by absorbing the nitrous gas by the sulphate of iron, and by thus separating it from the azot ; but M. Berthollet has proved, that no azotic gas exists in nitrous gas, and that what is obtained by the action of the sulphate of iron, proceeds from the decomposition of the nitrous gas over the sulphate. M. Berthollet has shewn, at the same time, that the greater or less force with which the acid is decomposed, yielded nitrous gas more or less charged with oxygen, and that this was the cause of the differences between the nitrous gases ; hence he concludes, that of all the eudiometrical processes, that of the nitrous gas is least to be depended on.

Among the substances which are combined with oxygen, we ought to prefer, for eudiometrical experiments, those which form a fixed produce, without liberation of gas or absorption of azotic gas. A sulphuret of alkali, dissolved in a small quantity of water, is one of the most perfect eudiometrical methods ; it

has only one inconvenience, that of taking up a great deal of time to finish the operation ; it may be accelerated, however, by agitation.

Messrs. Achard, Reboul, and Seguin, have successively proposed eudiometrical apparatus, formed upon the combustion of phosphorus ; but the rapid and tumultuous combustion of phosphorus must produce inconveniences ; and in the slow combustion, the azotic gas dissolves phosphorus, as M. Berthollet has shown ; and the phosphorus thence assumes an elastic state, which causes an increase of volume in the azot : so that we cannot rigorously determine the proportion of the oxygen gas by that of the residue. M. Berthollet has appreciated this increase in volume, by the solution of phosphorus in the azotic gas, at about one-fortieth.

Mr. Davy has proposed another eudiometrical method, which is the muriate of iron impregnated with nitrous gas : this solution produces the absorption of the oxygen gas in some minutes ; but we must seize the moment of the greatest diminution, because the nitrous gas is in part decomposed, and in proportion

as the salt of iron is oxydated, both azotic and nitrous gases are extricated.

The observations made by Messrs. Cavendish and Davy in England, by M. Berthollet in Egypt, by Mr. Macarthy in Spain, by Mr. Beddoes, upon the air on the coast of Guinea; by M. Gay-Lussac, upon the air elevated 4000 fathoms above Paris, and compared with the air at the surface of the earth;—all these observations have proved, that there is no sensible difference in the atmospheric air relative to the proportions of its elements.

Mr. Macarthy, who operated upon the air with a sulphuret, establishes the proportion of the oxygen at from 21 to 23 in 100. The proof by Volta's eudiometer only gives 20. M. Berthollet has found 22 and a fraction. Mr. Davy reckons it at 21.

The atmospheric air always contains a little carbonic acid, which is estimated at 0.01. M. de Saussure found this in the air of the summit of Mont-Blanc.

Other substances are mixed or dissolved in the air, but some of them do not produce any difference in the eudiometrical results,

Although this difference is strongly perceptible to our senses. Thus, the air charged with the odoriferous corpuscles of plants, or with emanations from substances in a state of putrefaction, presented no difference to Mr. Cavendish from the common air.

CHAPTER II.

*Of the combinations and mixture of the earths
with each other.*

NATURE, almost never presents to us the primitive earths in a state of absolute purity : not only are they mixed at the surface of the globe, where all is in action, and where life only exists in consequence of the continual movements and changes which take place upon bodies, and which form every instant, mixtures, combinations, and decompositions ; but the nucleus of our planet, which would seem to be free from all these alterations, is itself composed of one enormous stony mass, in which all the principles are mixed and confounded.

It is not the same with the earths as with the metals : the latter, equally spread over some points of the globe, presenting little facility of being displaced on account of their gravity, are almost every where found in an isolated mass, and appear to have been melted or precipitated into crevices or furrows, which

pervade the stony masses into their very centre: iron alone, very easily altered by the action of air and water, and then forming a very minutely-divided body, is easily carried off by the waters, and mixed with all the substances these waters penetrate; this is the reason why this metal exists almost every where.

The earthy, light, friable substances, susceptible of being divided and carried off by the action of the waters, are continually the sport of this fluid which penetrates them, of the winds which displace them, and of the changes of temperature which every instant alter and modify their solidity. Thus, had nature separated and circumscribed all the primitive earths, the meteors would have soon mixed and confounded them.

Although there is a great difference between the earthy mixtures and the metallic alloys, since there is penetration and combination in the latter, yet the former must not be regarded as the works of chance; because from that moment, there would be nothing constant nor regular in the composition of the earthy part of the globe, and all classification would become useless: the fortuitous mixtures of the

day would destroy the order observed in the night ; and analyses, and ascertained physical properties, would present results useful for the moment only. Affinity is a power continually in action ; it acts without intermission upon all bodies ; the minutely-divided earthy principles experience a continual action from it, which collects and unites them in determinate and constant proportions, and impresses the seal of perfection on the most of them, viz. crystallization. Thus we see stony crystals are formed, which constantly present, upon analysis, the same earthy principles, at the same time that the mixtures acquire hardness, which announces an union of parts determined by affinity rather than by gravity, or any other mechanical cause.

If we should pretend to make known in detail all the earthy mixtures which nature presents to us, we should give the picture of all the mineral productions of our globe. I shall confine myself to those only which have a direct application to the arts.

SECTION I.

Of the mixture of the earths with respect to vegetation.

Earth is not the nutritive principle of vegetables; but it fixes their roots, and receives into it their principal aliments, to transmit them to the vegetables as they require them. In this double respect, it necessarily has characters, and unites properties, which none of the primitive earths present to us, and which cannot exist, except in well-proportioned admixtures.

The most common earths are lime, alumine, silix, and magnesia. The two first, which have properties very different from each other, give their predominating character to almost all the earths which serve for vegetation.

The earths where alumine prevails are all the fat, clammy, and argillaceous earths; they crack upon drying, they are easily impregnated with water, and are susceptible of being shaped in the lathe or with the hand, so as to assume all possible forms.

The earths in which lime predominates are

porous, light, very permeable to water, and easily wrought; forming a paste, which has almost no consistency; receiving no sensible contraction from the fire, but dividing themselves therein, while the aluminous acquires hardness, and decreases in bulk, in the fire.

The first receive water with avidity, and retain it obstinately; the calcareous earths also receive it with avidity, but they allow it to escape with still more facility.

The first crack, divide, and open by the action of a burning sun, or of a dry wind; the latter dry without undergoing so considerable a contraction.

The air easily penetrates through calcareous earth, and may vivify seeds at a certain depth; while they rot when deposited in argillaceous strata.

An argilly soil clots the ploughing utensils, which open it with difficulty; and very rarely do we find advantageous seasons to labour it in: when these earths are dry, they present insurmountable obstacles to ploughing; when they are wet, they clog every thing that touches them. The grain sown upon them may rot by the prolonged effect of the humi-

dity ; and when the plant has come up, and the heat or the wind dries the surface, the stalk is strangled by the earth which is hardened, and it is impossible for it to come through.

The calcareous earths are more easily laboured : they are easily penetrated by air and water ; they permit the roots to extend, in order to collect the nutritive juices from a distance, and to give a fixed support to the vegetation. But the water, which enters into these earths without any resistance, escapes from them with equal facility. Soil of this description is alternately inundated and dried up ; and the plant, which cannot withstand all these alterations, languishes and dies in such a soil, where the dryness or humidity is too much prolonged.

Neither of these two kinds of earth, therefore, is proper for vegetation : nor does nature ever present them to us in a state of absolute purity ; they form every where mixtures, where their proportions vary *ad infinitum*, which occasions a great variety in soils, and establishes several qualities in them, according as the one or the other predominates.

The best soil for vegetation is that which unites the following qualities :

1st, It should be porous enough to permit the roots to spread, to ramify, and to collect from a distance the nutritive juices the plant requires.

2d, It should be sufficiently compact to give the plant a fixed and solid support.

3d, It should be capable of being impregnated with water, and of retaining it long enough to supply the wants of the plant.

The calcareous and the argillaceous earths, properly so called, do not unite these three qualities : the former are dry and warm ; the latter are humid and cold. The calcareous earths take in and abandon water with the same facility ; so that the vegetable is thereby exposed to the alternatives of being inundated or dried up. The argillaceous take in and preserve water in such a manner, that a plant may perish of dryness in the midst of an earth which is penetrated with moisture.

The bad qualities of the one of these earths, may be corrected by the properties of the other : and it is in the mixture of both that we shall find the most convenient proportions for an earth destined for vegetation.

Let it not be concluded from what I have now said, that we cannot cause to enter into

the composition of a good earth, other principles than those two I have mentioned : sand, plaster-rubbish, and silex, may amend argillaceous earth with the same advantage as they may calcareous earth.

Tillèt communicated to the Academy of Sciences, in 1774, the results of 54 earthy mixtures employed in the culture of wheat : it results from this communication, that the most favourable mixture to vegetation was formed of three-eighths of potters' clay, two-eighths of river sand, and three-eighths of oyster shells, the whole bruised, and carefully mixed.

It seems to me, that, by setting out from these principles, we may easily judge in what manner we may ameliorate a soil ; it is easy to conclude from them, that the methods should vary according to the nature of the earths ; and that the first care of a farmer should be, to study well the nature of his lands, in order to find out the plan of amelioration most proper for them.

SECTION II.

Of the mixture and combination of the earths with respect to potteries.

None of the primitive earths, treated separately, present to us the union of all the qualities necessary to form a good potters' clay; and it is also to the well-contrived mixture of some of the earths that we are indebted for this production of the arts.

We shall comprehend under the general title of *pottery*, all the productions of the art, from the coarsest manufactory to that of the finest porcelain: the whole art consists in the proper mixing of two or three earths; the only difference in the results proceeds from the choice of the earths, from the care taken in their preparation, the proportions in which they are employed, and from the nature of the baking and degree of heat to which they are subjected.

There are, therefore, some general principles which apply to all these operations, and which tie them, if I may be allowed the expression, to one common trunk: these are

the principles which are necessary to be known, in order to join again to them processes, which, although isolated and separated in practice, flow from the same laws, and should be elucidated by the same doctrine.

We may regard alumine as the base of all the potters' earths: the property it possesses, of dividing itself in water, and forming a paste susceptible of being manipulated, turned in the lathe, ground, &c. in order to assume easily and preserve all the forms we may wish to give it; the faculty which is peculiar to it, of becoming so hard in the fire that it will strike fire with steel; of scratching glass, and of uniting, by the application of a violent heat, so as to assume a smooth and almost vitreous surface without fusion; and of no longer being divisible or dilutable in water; have caused alumine to be adopted in preference to all the other earths.

But this earth is not free from inconveniences: it contracts upon being fired, and can bear with difficulty a sudden transition from cold to heat. These defects are remedied by mixing it with sand or siliceous earth, which being infusible like itself, do not sensibly con-

tract in the fire, and form a kind of frame, which by isolating, as it were, the argillaceous molecules, admits of their being subjected, without inconvenience, to the alternate transitions of heat and cold.

Besides, the mixture of these two substances forms, by the act itself of the fire, a kind of compound, the properties of which may differ from those of its constituent principles.

On examining more closely the principal qualities of baked earths, we shall perceive the reason of their greater or less resistance to being broken by the sudden change of temperature: in fact, it is known that the earthy substances are bad conductors of caloric; so that when we apply heat to the surface, it produces its effects of contraction or dilatation before being able to penetrate to the same degree all the mass; it must therefore have unequal effects, which tend to break the whole. This effect must be still more sensible when the earthen-ware presents a great inequality of thickness. But when we multiply the pores, or the small apertures, by means of sand, the fluid of heat circulates more freely; the mass is more equally heated, and nearly at the same

time; and the vessel resists alternate heat and cold. This property may also be given to it by applying the heat gradually; the changes then take place slowly, and at once over all the parts.

But the alumine is rarely pure, it is naturally mixed with lime, silex, magnesia, oxydes of iron, copper, manganese, &c.; and it is the nature of these mixtures, and the proportions among the bodies which form them, that give to argils infinite modifications in their properties.

Among the number of these natural mixtures, there is one of them which only requires the hand of the potter to shape it into useful utensils. For this reason, we see manufactories of coarse earthen-ware established upon the very stratum of clay which supports them; but more frequently these argils require a particular operation, and must be mixed with other earths, to make them of use for the purposes for which they are wanted.

In general, it is only from well conducted experiments that we judge of the quality of an argil, and that we determine the nature, and proportions of the substances most proper

to add, in order to render it fit for producing good ware.

It is almost needless to observe, that we must not expect the same qualities for every kind of ware, since these qualities are relative to the different uses to which the ware is to be applied : thus, in order that an earth should be fit for making pipes for a drain, house-tiles, or bricks, it would be ridiculous to require that it should resist the most violent heat, or undergo the sudden transitions of heat and cold. In this case it is sufficient if the mixture acquires hardness enough to prevent water from softening it or penetrating it.

Those wares destined to undergo a violent heat and sudden transitions of temperature, such as crucibles, retorts, furnaces, &c. should be likewise inattackable by all the bodies which we intend to work in them.

The ware employed in our kitchens would be of very limited use, if they did not undergo, without alteration, a sudden change of temperature, and if they were not compact enough to prevent liquids from filtering through them.

When we possess a pure clay, furnished with the requisite qualities for forming the base of a

good earthen-ware, we may apply it to every purpose, by well contrived mixtures. It is necessary therefore to know the qualities which constitute a good clay, before attending to the nature and proportions of the earths we ought to mix with such as do not possess all these good qualities, in order to apply them to every purpose.

A good clay has the following characters : 1st, it divides or melts in water, without any nucleus remaining ; 2d, it is precipitated in this liquid, without leaving any thing suspended which injures its transparency ; 3d, the deposit which is formed in the water, dried to the consistence of a soft paste, should have so much toughness and ductility, that we may easily work it by a lathe, or by the hands ; 4th, it should neither lose its form nor consistence, on drying in the air ; 5th, it should harden upon the application of heat, without cracking, without being deformed, or melted ; 6th, it should undergo, when fired, the sudden transitions from heat to cold, and vice versa.

A clay possessing all these properties, is a natural mixture of various earths ; for no one in particular possesses them all.

When a slight part of oxyde of iron, lime, or plaster, is united with the earth we are speaking of, the earthen-ware made from it presents a brilliant and vitreous gloss and fracture, at the same time that they acquire such a hardness that they strike fire with steel, and break nearly like glass. These wares *sound well*, as it is called, and they are capable of containing corrosive liquids, without being penetrated or altered by them. They would be the best earthen-wares known, if they could undergo, without accident, the sudden transitions of temperature. This is what is called stone-ware: it resembles much the biscuit of porcelain, from which they do not essentially differ, except in the grain, the colour, and the semi-transparency.

The most common argillaceous earth, which is called *fat earth*, and *potters' clay*, and of which the coarser ware is made, is a natural mixture of alumine, silex, lime, and a little oxyde of iron. The silex generally predominates; the alumine is in the proportion of about one-half: this is, at least, the mean result of all the analyses I made of these earths.

When the argillaceous earth is too rich in alumine, it is usual to mix pounded flints or sand with it, in order to correct the defects of too pure argil. Pott has already observed, that if we mix sand with clay, it is more advantageous to employ that which is of a middling size, which confirms the theory we have already given upon the permeability of heat through vessels.

Frequently, in place of sand, fired clay is used : this mixture is preferable for the manufacture of crucibles and glass-house pots, which must keep alkalis in fusion, because these latter substances would attack the sand in order to form glass.

When the clay contains pernicious substances, from which it must be freed, it is carefully examined, the ochery veins are thrown away, as also the pyrites, and other matters which alter its purity. By means of water, we may afterwards free it from the calcareous earth, which floats above, and from the sand, which is precipitated.

These are nearly all the general principles upon which the art of the potteries is founded ; and although there has been established in

society, an enormous difference between the coarse earthen-ware which the common people use, and the porcelain with which the rich decorate their tables and ornament their apartments, it is not less true, that in both cases, the nature, the preparation of the earths, and even the management of the fire, differ in some respects only. After having therefore related the principles which science presents to us as applicable to the art of the potter, it only remains to us to give some details, essentially connected with each of the branches of the art.

The choice of the earths, and the proportions in their mixture, differ according to the nature of the works we mean to execute. But when the choice and mixture are made, the working of the paste and the baking of the article, present a course of processes, in which there is no difference, except in the more or less care which the artist takes in these different operations.

The preparation of the earths is always confined to giving them an extreme minuteness of division, by means of water, with which they are impregnated. They are disposed to this preliminary operation by reducing them into

small fragments, or into powder, by means of mallets, of mills, or other mechanical methods.

The water employed should be pure, particularly when delicate pieces of ware are to be made; for this reason, in some manufactories of porcelain, rain-water only is used.

The earths are allowed to soak or *rot*, as it is termed, for a longer or shorter period, according to the nature of the earth, and that of the work we wish to produce. The longer the earth is in the pit to soak, the better it is prepared. Not only are the bituminous or vegetable principles, which exist in some earths, destroyed, but any sulphuric salts they may contain are decomposed; and it almost always happens, that after some time, sulphuretted hydrogen gas is liberated.

By their being allowed to remain some time in the pit, the earths acquire more tenacity and toughness, so that they can be wrought more easily. On this account, in some celebrated manufactories in Germany, they soak the earth at two seasons in the year only; and the time of the equinoxes is chosen, because it is generally thought that rain-water is more

strongly charged with fermentescible principles at these two seasons.

When the earths are prepared for delicate and precious works, such as porcelain or china, care must be taken to remove every thing which might alter the paste, and not to use any tools which might mix any prejudicial substance with it. The earth is even purified by a very simple process: for this purpose, after having bruised the earth, which is afterwards diluted in rain-water, it is put into a cylindrical cask, three or four feet high; this cask has stop cocks placed in its side, the one above the other, at six inches distant from each other, so that the lowest one is about two or three inches from the bottom. This cask is filled with diluted clay; the liquid paste is carefully stirred; and after settling for a few seconds, in order to allow the sand to precipitate, the upper stop-cock is turned, in order to draw off all that is above it: the second is then opened; the third, and so on, until the whole of the liquid which holds the earth suspended in it, is drawn off.

The decanted liquor is put into vessels of baked clay: the clay suspended in it is allowed

to precipitate ; the water is decanted, and the clay is collected, which is dried in the shade, and out of the reach of dust.

This clay, mixed in just proportions with calcined silex, pounded and ground, sometimes with bruised fragments of old earthen-ware, with baked and sifted gypsum, and other substances, forms the composition of porcelain ; and this composition is sifted several times through hair-sieves. The mixture is afterwards moistened with rain-water, in order to form a paste, which is put into covered casks. This paste is called, by the workmen, the mass. A fermentation soon takes place, which changes its smell, colour and consistence. Sulphuretted hydrogen gas is formed ; its colour passes from white to deep grey ; and the matter is tougher and softer. The older this mass is, the better it succeeds. It must be carefully moistened from time to time, to prevent it from drying.

The preparations of the mixture, and the art of rightly managing the mass, are secrets in almost all manufactories.

It is needless to repeat, that the care taken in the preparation of the earths, varies according to the work intended to be executed. In

the potteries of coarse earthen-ware, the earth is put to soak in pits dug under the open air, and they are moistened with any kind of water. When it is wanted afterwards, the quantity is extracted from the pit the occasion requires.

The second operation is to give the paste the form we wish, and this is done in three ways—1st, by the labour of the hands; 2d, by means of moulds; 3d, by means of the lathe.

The choice of one or other of these methods is not in the power of the artist; the nature of the works, their size and form, must determine the employment of this or that method.

In every case, where the paste is well prepared for working, a new perfection is given to it, by mixing it and kneading it with the hands, and even by beating it upon tables with large round pieces of wood: this is what is called, *dressing the earth*. By these mechanical operations, the earth is well divided, well mixed, and of an equal consistence.

The works which are made with the hand, are — 1st, all sculptures, which are afterwards baked, in order to give them the con-

venient hardness ; busts, and other ornaments, are of this description ; 2d, good glass-house pots, for by this means the earth is better dressed than it can be by the lathe.

The works done in the mould, are tiles, bricks, &c. The mould, of wood or iron, is of the form proposed to be given to the piece : it is open at the two faces, so that it is, properly speaking, merely a frame, for the purpose of giving equal dimensions to the various works we are doing. This frame is used on a table covered with a little sand or ashes, to prevent the adhesion of the paste : the frame is then filled with prepared clay ; by the help of a cutting instrument, which we apply with both hands over the top of the mould, the excess of clay is taken off.

Almost all vessels of a cylindrical form, or which are hollow, are wrought with the lathe : we begin by moistening the paste we wish to turn ; and it is kneaded with the hands, to give it the requisite softness. The workman afterwards takes the quantity he thinks necessary for his work. He sticks this piece of paste upon the middle of the horizontal wheel, to which he gives a rotatory motion, by push-

ing with his foot the lower wheel, parallel to, and fixed to the same axis ; and with his hands, which he applies forcibly to the paste, he shapes his work, which he finishes by wooden tools, applied to the sides of it, while moving rapidly round, in consequence of the motion given to the wheel, so that the action of these mechanical agents is equal over all the points of the circumference ; the workman then successively employs his hands and tools, until his work is finished.

When it is wished to give a work the most perfect finishing possible, it is again carried to the lathe, when it has been dried a little, in order to render its forms more delicate and finished, by means of various steel instruments well sharpened.

Sometimes several of these processes are united in the execution of a single piece of workmanship. For instance, after having roughly given the principal forms, the workman soaks the piece in water, and places it in a plaster mould ; afterwards, by means of a wet sponge, with which he presses all the points of the surface, he fits his piece of ware to every part of the mould, and makes it

assume the exact shape. The moulded figures are then withdrawn, in order to dry them.

The labour of the potter who makes figures is not so tedious, but it requires more address. The modeller, as well as the turner, has plaster moulds, in which he casts the paste; and having left it some time in them, in order to give it consistence, he extracts from it the moulded figures. But these figures very rarely come out whole, being moulded in pieces, which are afterwards cemented together. They are then finished off with ivory tools, a pencil, and a sponge, and after this they are dried.

It is unnecessary to observe, that the mould-works require the assistance of an experienced sculptor: each piece is numbered in order to ascertain its place.

Ornaments, flowers, fruits, and foliage, are formed separately, in moulds, and afterwards affixed with diluted paste.

A third operation, common to all potters, is *baking*, or *firing*: the construction of the furnaces varies, according to the nature of the potteries; in general they are round or square towers, the interiors of which present two very distinct parts, separated by an arch pierced

with several holes, which give a passage to the flame.

We may employ, almost indiscriminately, all kinds of combustibles in the firing of coarse earthen-ware; but, in general, that which gives most flame is preferred; and when we bake porcelain, we make use of very dry white wood alone, cut into small billets of an uniform size.

The baking of porcelain and fine earthen-wares demands particular attention: we are obliged to enclose every separate piece in a case or frame, formed of a very porous paste, and which resists the action of heat; by this means we prevent the pieces baked from running or adhering to each other; and we also prevent any alteration which the smoke might produce in their colour.

The firing of porcelain generally lasts from 36 to 48 hours. We judge of the state of the baking by *proof-pieces*, as they are called, placed in convenient situations, and which we can draw out and examine from time to time.

It often happens, that the pieces of porcelain adhere to the sand which has been spread upon the bottom of their case or frame, in

order to prevent immediate contact : the piece thus soiled, is applied to an iron wheel, upon which is placed emery bruised in water, and the half vitrified sand is thus completely removed. This is the reason why the bottoms of porcelain vessels are never covered with varnish on the place which rests upon the sand.

There are some earthen-wares, which, after one baking, attain all the perfection they require : such as furnaces, crucibles, earths made into bricks, &c. But those productions of the pottery, intended to hold liquids, would be porous and ill suited to the end for which they are destined, if they were employed after a first firing. It is usual to cover the surface with a vitreous coating, which does not admit of water penetrating : it is this vitreous coating which is called *varnish* or glazing, in speaking of coarse or brown earthen-ware ; *enamel*, in speaking of the white earthen-ware ; *covering*, when the finest production of the potteries, porcelain or china, is mentioned.

The varnish of the coarse earthen-ware is made of lead : for this purpose the oxydes of lead are employed, such as *minium* or litharge,

or rather the sulphuret of lead, which mineralogists call *galena*, and which is known in the language of commerce, and of the potteries, by the name of *alquifou*, or *potters' ore*.

Whatever is the nature of the substance which forms the varnish, it is not employed until it is so well pounded that it remains some time suspended in water ; and it is applied to the surface of the earthen-wares previously well dried, or by soaking them in water charged with it, when we wish to cover every part of their surface with varnish, or by throwing the same water upon such parts as we may wish to varnish, separately and distinctly from the rest.

I have had occasion to be convinced, that in the greatest number of establishments of the common kind of pottery, they begin by drying in the shade the pieces they wish to varnish ; and that when they have acquired the necessary degree of consistence, they are plunged into water which holds suspended in it a fat earth, extremely minutely divided, and previously passed through a silk sieve ; the pieces are then hastily drawn out, covered by this operation by a slight coat of this earth. The

colour of these earths forms the ground of the colour of the ware ; and when a green colour is wanted, a little copper filings are added.

Upon this coat of fat earth, a little dried, we may apply the sulphuret of lead, by projecting water charged with this mineral upon the ware : but it is almost every where mixed with equal parts of sand ; the mixture of these two substances is pounded, so as to render it impalpable ; it is soaked in water, and the piece of ware is covered with it where we wish to lay on the varnish.

It is easy to see, that by this method we may vary and shade at pleasure the colour of the ware : it is only requisite to apply separately, upon the different parts of the surface, the fat, yellow, white, or red earths, and mixed or not with copper-filings.

Some potters do not apply the varnish until the ware has undergone one firing ; in this case they employ less varnish, as they only apply it to those pieces which have resisted the action of the fire ; but the second firing which becomes necessary, requires more workmanship, consumes much more combustibles ; and it is

for the artist to calculate the advantages and disadvantages of these two methods.

A black and vitreous colour may be given to earthen-ware, by throwing into the fire at the time of its greatest heat, some coal in powder or dust; the draught of the fire is consequently checked, so that it is filled with a thick smoke, which is deposited upon the ware, and forms a coat, which is vitrified as soon as the current of air rekindles the fire.

On throwing common sea-salt upon a well-heated fire, the salt is volatilized, and attaches itself in part to the softened surfaces of the earthen-ware, where it produces a commencement of vitrification.

These two last methods are only applicable when the fire is very strong, and where the ware can undergo a sudden heat without flying or melting. It would be impossible to practise it however in our common potters' furnaces.

I endeavoured for a long time to find a substitute for the sulphuret of lead, by a varnish which should unite the same advantages, and be at the same time more economical. I first

tried pounded glass ; and I obtained very satisfactory results from it.

I begin first by pounding with great care, pieces of clear broken glass, and when I have reduced them to a very fine powder, I sprinkle with this powder the surface of the earthenware, covered with a weak coat of fat clay, according to the process above described.

We may also mix this glass-powder with fat clay, dilute the whole in water, and plunge into it the dried pieces : this second process succeeds extremely well.

This varnish covers well, it is not dangerous to use it, it is very economical, and does not require so much heat as the former. Since the year 1782, when I made it known, and executed it on a large scale, it has received some useful improvements in the potteries of Normandy, Languedoc, and Venaissin.

I have also employed with success, volcanic products, which I treated in the same manner with the other varnishes. I transmitted in 1785, to the Comptroller-general of the Finances, a considerable quantity of bottles made of lava, and pieces of earthen-ware varnished with lava, that he might submit them to ex-

periments, and have their quality ascertained : the results of these experiments were very favourable. M. Fourmy derived great advantage from this, by applying it to the manufacture of water-coolers, which he established at Paris.

The enamel with which the earthen-ware called Delft, is covered, is merely glass, rendered opaque by the interposition of the oxyde of tin, which requires, in order to pass to vitrification, a greater degree of heat than the other substances which are mixed with it.

Every artist has his own recipe and process for making his enamel, but all of them take lead and tin as their base, which they oxydate and mix in various proportions, with well-burnt sand.

The composition which furnished me with the finest enamel was the following : we begin by calcining with great care, equal parts of lead and tin : when the two metals pass to the state of oxyde, and present a fine powder only, they are carefully pounded and passed through the sieve : this powder is then boiled, and water is thrown upon it after the deposit is formed ; a fresh quantity of water, is poured

upon the deposit in order to dilute it; we then decant the water, which holds in suspension the most minutely divided parts, and we allow it to settle. The residue is pounded, sifted, and treated with water in the same manner; and by repeating this course of operations several times, the whole is brought to the same degree of fineness and tenuity: this powder is afterwards dried, in order to use it as occasion requires.

On the other hand, we calcine very white flints, free from all foreign matter, and purify them from the salt of tartar, so that we have only a carbonate of potash.

These three substances being thus prepared, we weigh 100 parts of mixed oxydes of lead and tin, 100 parts of calcined flint, and 200 parts of carbonate of potash: all these are well mixed, and melted in a crucible.

Merret has suggested the substitution of white oxyde of antimony for the oxyde of tin. Darcet also observed, that a fine enamel was obtained by melting white clay with gypsum. But these processes are not yet sufficiently confirmed by experiments, to entitle them to be adopted in the manufactories.

The enamel of Delft ware, may be coloured by adding various metals to the composition.

Composition of the coloured enamels.

1st, Three ounces of zaffre, and 60 grains of calcined copper, added to six pounds of the enamel composition	Colour. Azure blue.
2d, Six pounds of white enamel, three ounces of oxydated copper, 98 grains of zaffre, 48 grains of manganese	Turkish blue.
3d, Six pounds of white enamel, three ounces of oxydated copper, 60 grains of iron-filings	Green.
4th, Six pounds of white enamel, three ounces of zaffre, three ounces of manganese	Shining black, or deep blue.
5th, Six pounds of white enamel, six ounces of red tartar, and three ounces of manganese	Very brilliant black.
6th, Six pounds of white enamel, three ounces of manganese	Purple.
7th, Six pounds of white enamel, three ounces of tartar, 72 grains of manganese	Yellow.
8th, Six pounds of white enamel, three ounces of oxyde of copper, 60 grains of zaffre	Sea-green.
9th, Six pounds of white enamel, two ounces of manganese, 48 grains of oxyde of copper	Violet.

Whatever be the nature of the enamel, when we wish to apply it, it must be pounded and diluted in water, and we must throw this water which holds it in suspension, upon the vessels which have been already fired once; the water is absorbed into the texture of the ware, and the enamel powder remains on the surface. A second firing, stronger than the first, must be given to the ware, in order to melt the enamel.

As it is material to preserve its fine white colour to the Delft ware, it must be fired in cases, in the same manner as porcelain.

The earthen-ware of the celebrated Mr. Wedgwood, having acquired great celebrity wherever it is known, under the appellation of *English ware*, or *Wedgwood's ware*, we shall make known the principal compositions which form the colours of this ware. They may, perhaps, be imitated in France, where this branch of industry has begun to make great progress.

First process, or preparation of the ingredients.

No 1. A white earth from Ayoree, in North America : calcine this in a red heat about half an hour.

No. 2. *Bronze powder.* Dissolve one ounce of pure gold in aqua regia ; precipitate it with copper ; then wash the precipitate with hot water, till it is sweet, or clean from the acid : dry it, and lay it up for use.

No. 3. Take two ounces of crude antimony, levigated, two ounces of tin-ashes, and six ounces of white-lead ; mix them well together, and calcine them in a potter's furnace, along with glass cream-coloured ware.

No. 4. Take eight ounces of good smalt, one ounce of roasted borax, four ounces of red-lead, and one ounce of nitre : mix the ingredients well together, and fire them in a crucible, in a potter's biscuit-oven.

No. 5. Take English copperas or vitriol of iron ; calcine it in a moderate red heat about two hours ; then wash it in hot water, till it is sweet : dry it, and lay it up for use.

No. 6. White lead.

No. 7. Flint, calcined and ground.

No. 8. Manganese.

No. 9. Zaffre.

No. 10. Copper, calcined to blackness.

Second process, or compounding and mixing the colours.

Shining black, A. Three ounces of No. 8, three ounces of No. 9, three ounces of No. 10, eleven ounces of No. 6, six ounces of the green F.

Red, B. Two ounces No. 1, two ounces No. 8, one ounce No. 5, three ounces No. 6.

Orange, C. Two ounces No. 1, fourteen ounces No. 3, half an ounce No. 5, four ounces No. 6.

Dry black, D. One ounce No. 4, two ounces No. 8.

White, E. Two ounces No. 1, two ounces No. 6.

Green, F. One ounce No. 1, two ounces No. 8, 5 ounces No. 4.

Blue, G. One ounce No. 1, five ounces No. 4.

Yellow, H. No. 3 alone.

Third process, or application of the encaustic bronze and colours.

Application of the bronze :

I. When the vessels are finished ready for burning, and before they are quite dry, grind some of the powder No. 2, in oil of turpentine, and apply it to the vessels or figures with a sponge or pencil, to imitate bronze, in such manner as your fancy directs : polish this powder upon the vessel or figure, and burn it, in such a furnace, and such a degree of heat, as is necessary for the ware ; after it is burnt, burnish the bronze upon the vessel to what degree you please, and the process is finished.

Another Method of applying the bronze after the ware is fired biscuit, as some figures or vessels may be too delicate to bear the process I.

K. Take four ounces No. 6, and one ounce No. 7 ; grind them well together ; spread this very thin, with a sponge or pencil, over the ware to be bronzed, and fire it till this layer

of size is fluxed, which may be done in a potter's furnace ; then take the powder No. 2, and apply it to the vessel, as before directed ; then burn the ware over again, till the powder adheres to the size : burnish, &c. as before.

Application of the shining black upon red vessels, in the manner of the antique Etruscan vases.

L. Take the colour A, grind it very fine with oil of turpentine, and with it trace the outlines of the design you intend to have upon the vessel ; then fill up the vacant spaces very even, and shade the drapery, &c. Fire the vessels in a heat sufficient to flux the black, and they are finished.

Another method to produce a different effect with the same colour, in the manner of the Etruscans.

M. Paint the design, with the black laid on as dead colouring, upon the red biscuit-ware ; and cut up or finish the design with red and other colours ; for which purpose the above-

mentioned ones are prepared : they must also be ground in oil of turpentine, and burnt upon the vessels in a muffle, or enamel-kiln.

Another method to produce, in a more expeditious way, nearly the effect of the process L.

N. Take the red, B, or the orange, C, and lay in your design with it, as a dead colour, upon black biscuit vessels ; and shade it with the black, D, with or without the addition of any of the other colours ; firing them upon the vessels, as before directed.

The covering of porcelain is a vitreous and transparent matter, which must be applied exactly over all the points of the surface, and incorporated with the paste, without cracking or flying.

Count Milly, who, in his work upon porcelain, has made us acquainted with three compositions for the covering, makes them consist of the same materials, varying the proportions only.

	<i>First Composition.</i>	<i>Second Composition.</i>	<i>Third Composition.</i>
Very white quartz,	8 parts,	17 parts,	11 parts.
White enamel,	15	16	18
Calcined crystals of gypsum,	9	7	12

Pure and colourless substances alone, must be used for the covering.

Feldspar, is also made use of.

Whatever be the composition, we must grind, with the greatest care, the substances which enter into it; their powder must be diluted in water, and a paste formed with it, which must be macerated in water like the mass of the porcelain.

When we use it, it must be diluted in water, so as to give it a tolerable liquidity; and we must plunge in this liquid, the porcelain which has already undergone the first firing*.

Figures, and generally all porcelain articles which are neither to be painted nor exposed to water, have no occasion for any covering; they are then sold in the state of biscuit.

When the biscuit has received its covering, it constitutes white porcelain; and in this state it may be applied to every purpose.

Hitherto we have only considered earthenware in respect to its utility; but art has so perfected this valuable branch of our industry,

* After the first firing, it is called *biscuit porcelain* in the French and English potteries.—T.

that we have succeeded in executing in earthenware the most complicated designs, with astonishing elegance and precision. There is no one who does not admire the beauty of form, the correctness of design, and brilliance of colouring, in the porcelains of Sevres, and those of Messrs. Dilh and Guerard.

Among these prodigies of French industry, some parts of them belong to the art of design, and some to chemistry—with the latter branch in particular we are now occupied.

The application of colours upon porcelain presents to us some very interesting points of view : on the one hand, the nature and choice of the colours ; on the other, the art of applying and incorporating them.

The colours are all derived from the metallic oxydes : these alone retain sufficient fixity to prevent the fire from destroying them. Nay, the metallic colours, although dull in general when applied, acquire lustré when they are subjected to the action of the fire.

The colours are incorporated with a flux, which varies in the different manufactories : the following composition is generally adopted :

	<i>Drachms.</i>	<i>Grains.</i>
Glass in powder, free from lead,	4	0
Calcined borax,	2	12
Purified nitre,	4	24

These substances are carefully mixed and divided, and then vitrified in a crucible.

This glass is afterwards ground, and incorporated with the colour. Gum or oil of lavender is used as a vehicle, when we wish to lay it on the biscuit. For this purpose, a pencil is used, and all the methods known in painting.

Oxyde of gold, called *precipitate of Cassius*, makes purple colour.

Gold, precipitated by tin and silver, produces violet colour.

Copper, precipitated from its solutions in the acids by the alkalis, furnishes us with a fine green.

The saffron of Mars and colchotar produce the reds.

Zaffre makes blue.

Diaphoretic antimony, mixed with glass of lead, forms the yellows.

The browns and blacks are made with iron filings, and strong doses of zaffre.

The oxyde of chrome forms a fine green.

M. Brongniart, director-general of the porcelain manufactory at Sevres, has already attained several very important improvements in this branch of industry ; and the manufacture of porcelain may expect great progress from the zeal and intelligence of this experienced naturalist.

SECTION III.

Of the mineral combinations with regard to vitrification.

We have already made known, in the first volume of this work, the action of heat upon a great number of simple or compound mineral substances : we shall now detail the art of making glass.

Glass presents a great variety of qualities : but as this essentially belongs to the proportions of the substances employed, and particularly to their different degrees of purity, we shall confine ourselves to detailing the general principles upon which vitrification is founded, and the principal operations by which it is executed.

Pure substances vitrify with difficulty, and the glass which proceeds from them is in general dry, and very brittle. But the same substances mixed, enter more easily into fusion. Alumine and lime, although invitrifiable separately, are easily reduced into glass, when mixed together.

The alkalis facilitate the fusion and vitrification of all the earthy principles. On account of this property, these salts are employed for forming the base of the composition of glass manufactured for our use.

Besides the degree of fusibility which the alkalis communicate to the earthy substances, they give to the glass which proceeds from their mixture with the earths, a pliability, which admits of its being wrought, blown, extended, and hammered while it is warm and soft.

The manufactories where glass is made, are called glass-works. The compositions, the working, and the furnaces, vary in the different manufactories, according to the nature of the glass made in them: hence the various denominations of *bottle-glass*, *flint-glass*, *plate-glass*, *crystal-glass*, &c.

But whatever may be the nature of the glass to be made, there are principles essentially dependent upon science which are applicable to all glass-works, and according to which all the operations are directed.

These general principles have for their object, every thing relating to the manufacture of the pots or crucibles, to the composition of the substances, to the construction of the furnace, to the management of the fire, and to the manner of working the glass. We shall glance at each of these subjects in succession.

ARTICLE I.

Of the manufacture of crucibles, or glass pots.

Good crucibles ensure the success of a glass-work. This truth can only be felt by those who have appreciated the loss occasioned by pots which break or melt, the loss of time, and the difficulty of replacing them.

Clay forms the basis of glass-house pots. But as the qualities of clays are very variable, because they are naturally and constantly mixed in various proportions, with lime, silex, iron, and magnesia, which renders them more

or less fusible, the clay must be picked before employing it.

The qualities of a good clay are as follow :

1st, It must not vitrify upon an exposure of several days in the hottest place of the furnace.

2d, It must preserve its form, without sinking down, or becoming soft.

3d, It must be wrought and moulded easily.

4th, It must undergo the action of the fire without contracting, or cracking.

5th, Good clay assumes, upon being fired, a very great hardness and compactness.

When we have ascertained all these qualities in the clay, it must be still picked, in order to separate from it every thing foreign or prejudicial. To this effect it must be carefully picked, in order to take out the pyrites, and all the small coloured veins, which render it fusible : we may content ourselves with raking the pieces tinged with ochre, and separating all the colouring principle from them.

After having taken away with our hands, or with a knife, every visible impurity, the clay must be diluted and soaked in water ; it is afterwards passed through sieves, in order to

prevent the water, weights, and inside from it.

It is better, if much, to not render it very the outside of clay, particularly if they are in small quantity: but mixtures of calcareous earths, plaster, putty, and other matters, render clay improper for glass-house pots.

As it is material to give to the sides of a crucible such a thickness only as to render it capable of resisting the effects of the substance it contains, and the shocks it receives in the work, M. Lavoisier has suggested, that we should calculate the tenacity of the clay, by forming small sticks of it in the form of parallelepipeds, which he dries at a temperature of 25 degrees of Reaumur, and one of the extremities of which he reduces to a diameter of six lines. He fastens this extremity in a cubical cavity: and at the distance of 18 lines he suspends from one of these sticks, the handle of a pair of scales, in which he places weights until they produce a fracture in the stick. He observed, that good clay employed for crucibles of three feet diameter by three feet six lines thick, did not break, except with

a weight of 56 inches ; and that of a furnace of fusion of eight feet diameter, by a weight of 24 ounces.

But clay, employed by itself, contracts too much, and it is mixed for forming the composition of pots, with the broken pieces of crucibles, ground, and well cleared of all vitrified matter, or with clay strongly fired.

Great care must be taken not to employ sand in forming pots, because the alkali employed in making the glass, would act upon the sand, dissolve it, and speedily destroy the crucibles.

After having prepared the clay well, it is mixed with the cement formed of ground fragments of crucibles, and a paste is made with it which has such a consistence, that a lead bullet of four ounces weight, may sink into it completely, upon falling from a height taken between 66 and 83 inches.

This paste must be dressed with the greatest care in a proper place, and out of the way of all dust, and the mixture of every foreign substance.

When the paste is thus prepared, either the

One or the other of the two following processes may be employed for making the crucible.

1st, In some glass-houses they have a wooden mould, furnished in the inside with a strong and well-stretched cloth. Rolls of paste are applied to the interior surface of this cloth, and the frame of the crucible is successively raised, by gradually diminishing its thickness from the bottom to the upper edge.

2d, In other glass-houses, the workman has a round piece of wood, a little broader than the crucible is to be, and he raises with his hand, and without mould, his crucible upon this kind of foundation.

This last method is preferable to the former, because the workman can work his paste at all places, and he leaves no cracks nor crevices in the body of the crucible, and he can join perfectly and uniformly all the parts. This process is particularly necessary in the bottle glass-houses, because this composition corrodes the crucibles more than any other.

When the pots are manufactured, they are allowed to dry in the shade, at a temperature of 10 or 15 degrees of Reaumur's thermome-

ter. We should equally dread a too strong heat, which might crack the pot; or a too sharp cold, which might freeze it; dampness, and currents of air, should be also carefully avoided: the apartment which serves as the drying-place should be shut, and very little frequented.

When the pots begin to be dry, they are inclosed in a close place, where the heat is constantly kept up to 25 or 30 degrees of *Reaumur*. From this they are brought out to be put in use. For this purpose, they are exposed by degrees to a heat which produces redness, and in this state they may be placed upon their seat in the furnace. Prudence requires, that they should not be charged with any composition after they are placed upon the furnace, until they have undergone the strongest possible heat for 24 hours.

ARTICLE II.

Of the construction of glass-house furnaces.

The paste intended for making the bricks of a glass-house furnace, is prepared by mixing crude with fired clay, or rather, with broken

pieces of crucibles : white infusible quartz, or a very refractory sand, are also employed instead of fired clay.

In order to pound the pieces of quartz more completely, they are made red-hot, and then thrown into water. This operation, as is well known, renders them pulverulent, without hurting their refractory quality.

Bricks are sometimes used which have not been fired ; these are merely dried in the air to such a degree, that a leaden bullet, falling from a height of from 25 to 45 feet, only sinks half its bulk into the brick.

The furnace of a glass-house is alway erected in the middle of a very spacious hall, in' order that the working and the service of it may be easy.

The draught of the furnace is effected by means of four currents of air, which enter the hall at separate apertures, and unite at right angles at the grate of the fire.

The interior form of the furnace is almost always that of a square, or of a rectangular parallelogram, the broadest sides of which are occupied by the pots, which are supported and fixed on trevets or shelves. The interval be-

tween these shelves, or trevets, forms the grate upon which the combustibles are placed. The fire is fed by apertures made in the sides: the pots are charged and emptied by means of openings immediately above them, and which exactly correspond with them, in order that the business may be more easily conducted.

The furnace is surmounted or terminated by an arch, which rests upon the two longest sides, and which is full of holes, in order to establish a proper draught, and to give a passage to the flame, which also heats other arches placed before these angles, or above the vault.

When, upon his return from the crusades, Louis IX. gave to some gentlemen who had followed him, the privilege of making green, or *chambourin*, glass, as it was then called, without derogating from their rank or honour, the principal establishments of this description were in the south of France, where they were constantly attended by gentlemen; in that part of the world, therefore, the aukward forms and compositions of the times are preserved without any change. The furnaces are of a round form; the fire is in the middle;

the arch is pierced in its centre, to give a passage to the flame, and to throw it into an upper and vaulted space, which serves to anneal the glass deposited there as soon as it is blown. The nobles exclusively work at these kinds of glass-works; they are contented with a very moderate profit; and neglect or despise, as a consequence of their principles, all the pecuniary advantages which are derived from glass-works, when conducted by men who do not belong to their class.

ARTICLE III.

Of the choice of the substances employed in the composition of glass.

Silex and the alkalis form the base of glass in all countries: the other ingredients are, properly speaking, only accessory, for facilitating the flux and purifying the glass, or for giving it any peculiar quality.

The purest silices and alkalis form the clearest glass, and it is this composition which forms the basis and regulation of all the operations of glass-houses.

But silex and alkali exist no where pure : it is only by troublesome, difficult, and expensive processes that we can bring them to this degree of purity. These substances are therefore very generally employed in the state in which nature and commerce affords them. Attention must be paid, however, among the varieties which these two substances present, to choose such as experience has shewn to give constantly the production we are desirous of obtaining.

In some delicate works, such as the making of fine crystal or plate glass, the alkali of commerce is purified, in order to clear it of all foreign bodies.

In general, white sand is the purest, but it is also the most refractory : the coloured sands fuse much more easily.

Alicant soda holds the first place among the alkalis of commerce. It is therefore most employed in the delicate operations of the glass-works.

Sicilian ashes, the *salicornia*, and sea-wrack, are employed in the manufacture of all the common clear glass.

Potash and salt are also well adapted for vitri-

It is also used in the manufacture of the
 various kinds of window-glasses and crystal-
 glass, &c. &c.

In France, the ashes of our fires, mixed with
 some of the tank water, are used to be-
 lieve. When the ash is very fine, it is used
 some way or other. I have seen most
 excellent white glass windows well finished
 with the tank-water, mixed with equal parts of
 water and vinegar or oil.

The salt contained in the alkalis enter into
 fusion, and swim upon the surface of the metal
 as the workmen call it, in the state of a very
 fine foam, which must be carefully taken off
 with a ladle or skimmer before beginning to
 work the glass. This operation is only ne-
 cessary when salts are employed highly
 charged with marine salt. The glass-works
 where these kinds of salts were used, made a
 considerable trade of the salt, which was sold
 by the name of glass-house salt, when the ga-
 lery or salt-cell rose to such an enormous
 height in France. Glass-house salt is also
 known by the name of gall of glass, or sandi-
 ver; and when the matter is not well melted,
 or when all the marine salt is not evaporated,

it is found dispersed through the glass in small grains, which injure much the beauty and solidity of the article.

When we wish to purify soda for delicate operations, it is dissolved in water, in order to separate, by a previous operation, every thing that may be insoluble ; it is afterwards evaporated, and concentrated to 40 degrees of Baumé's areometer, in order to precipitate the foreign salts, which crystallize ; the remaining liquor is afterwards concentrated to dryness, and by this means we obtain a very pure salt of soda. We may even obtain it in crystals, by stopping the evaporation at the degree of a syrupy consistence.

The proportions of the substances which form the composition of glass, vary according to the nature of the sand, the purity of the alkalis, the quality of the glass, and the degree of heat in the furnace. Experience alone must prescribe and determine the most proper composition : the more fusible the sand is, the less alkali it requires ; the purer the alkali, the greater is the quantity of sand which is necessary in the composition.

In order to facilitate the fusion of the com-

mineral, and to give the glass more ductility, more weight, and less hardness. oxide of lead is added in the composition in variable proportions according to the object in view. MINIMUM. of vertical is always reserved for the purpose of the irregularities of crystallization.

The oxide of manganese is also used, by the name of *glass-magnet* and, in order to clear the glass of all colouring matter. I presume its effect must be chiefly ascribed to the facility with which it gives up its oxygen, which combines with the colouring principles, and destroys them.

The much vertical makes the glass yellow; this defect may be corrected by applying a little red or a coat, which, in its turn, will produce a blue colour, if in excess.

The much manganese gives it a violet colour, and forms streaks, or violet-coloured vitrums, in the thick parts of the glass. This fault may be corrected by allowing a combustible body also the melted mass.

There are circumstances where a tried composition attains a proper degree of fusion with great difficulty; this may proceed from the

draught of the furnace being interrupted, or when the fire is ill managed; in this case, borax, or arsenic, must be resorted to for restoring the fusion. The latter substance is held in the bottom of the pots, until it has evaporated in fumes; it spreads through the whole mass, agitates it, and hastens the flux of it. Arsenic serves in particular for destroying the green colour of glass, besides the advantage it has of facilitating the flux.

The glass is coloured with the metallic oxydes; cobalt makes blue; manganese, violet; glass of antimony, yellow; precipitate of Cassius, purple; chrome, green, &c. Various colours may be obtained by the mixture of these oxydes; and we may obtain all the shades we desire.

ARTICLE IV.

Of the flux of the substances forming the composition of glass.

The flux of the substances embraces two principal operations: 1st, the fritte; 2d, the fusion.

If we throw into the crucibles the substance which forms the composition, without having prepared it by a previous strong calcination, the crucibles would be destroyed in a short time, in consequence of the water which would be disengaged on the first impression of the fire: the flux would be almost impossible, in consequence of the greater fusibility of the alkali, which would come to the surface; the glass would be coloured, and the paste itself would experience a swelling which would drive it over the crucible. In order to obviate all these inconveniences, the substances undergo the fritte, in all the glass-works, before put into the pots to be melted.

The fritte is conducted on the substances, either separately, or in their state of mixture and composition. The second method is preferable, for the reasons I have above given.

The fritte is executed in furnaces made in the hall of the glass-house; and which very often communicate with the melting furnace, from which they receive the heat by apertures made at the base of the great arch, and at the

angles. These places are then called fritte-arches.

The substances are fritted some time, keeping them red-hot, and by this means they often receive a commencement of a pasty fusion, which unites the parts of the composition, so as to form one mass.

The manufacturers of bottle-glass, already mentioned, give the form of bowls to their composition, in order to roast it more completely.

Others throw the composition, when well mixed, upon the bottom of the arch, taking care to strew it very thinly, in order that the calcination may act equally upon all the parts.

Previous to putting the composition into the melting-pots, a new activity is given to the fire, and it is stirred three or four hours before charging them.

The pots are charged at two, and even three times : a fresh quantity of composition is not added until the first quantity is melted.

As soon as the pot is filled, the fire is carefully kept up, for a longer or shorter time, according to the fusibility of the composition, and the draught of the furnace. Ten or

twelve hours is sufficient to melt the whole composition. But although it is well melted, it is not yet fit for working; it must be allowed to settle, to clear itself of the numberless bubbles which are dispersed through the paste; and this effect can only be produced by keeping the composition at a very liquid fusion for some hours. This operation is called *fining*.

When the glass is thus fined down, or rendered fit for working with, the heat of the fire is allowed gradually to diminish, by adding no more coals to it. The vitreous mass then assumes a little more consistency, which facilitates the work.

ARTICLE V.

Of working the glass in glass-houses.

The working of glass is very simple; but notwithstanding this, it requires a great deal of practice, and no one can expect to become a good artist in this branch of the business, if he has not acquired the art early in life.

Every thing respecting the working of the

glass, may be reduced to the art of *blowing* or *running* it.

In blowing the glass, an iron tube about five feet long is used ; with this the workman takes out of the pot the quantity of glass necessary for his operation : the air he exhales from his lungs through the hollow of the tube, into the mass of glass he has taken up, distends it ; he afterwards gives this mass, while it is distending, the form and dimensions he wishes. Compasses, scissors, and other iron tools are employed to shape, pare, or dilate the glass. Care is taken to present it to the furnace as soon as it begins to cool ; when again heated, and it begins to melt, it is withdrawn, in order to bestow additional labour upon it.

The softness of glass, when it is made red-hot, forms such a contrast to its fragility when it is cold, that it would be difficult to conceive how easily it may be kneaded, soldered, and distended, if we did not see it actually done before our eyes.

Much has been said of the malleability of glass ; researches have been made, in order to recover this *important* art, which it was thought the ancients possessed ; and people

have been unwilling to allow that there is no metal more ductile or more malleable than glass when red hot ; or that this art, supposed to exist among the ancients, is practised among the moderns every day in our glass-houses.

Plate-glass is formed by pouring melted glass upon a copper table, the surface of which is very flat, and by passing a level above the melted matter, in order to give the plate an uniform thickness. This operation is very similar to that by which metallic tablets are formed, by throwing melted metal upon sand.

In order that the glass may be less brittle, it is necessary that it should be cooled very slowly : this last operation is called annealing. In the large manufactories of bottle-glass, the glass is annealed in furnaces made in the angles of the hall where the melting furnace is : these furnaces are red-hot when the glass is deposited in them ; and as soon as they are filled with the glass articles, the apertures are closed, and the heat allowed to subside of itself.

In small glass-houses, the annealing-furnace is generally placed upon the melting-furnace, or at one side of it, so as to be heated by the current of flame which escapes from the fur-

nace; this is merely, properly speaking, the commencement of a very wide flue, and which insensibly diminishes in width the further it is removed from the fire: so that the glass deposited at its base gradually cools as it is drawn towards the extremity. The glass is annealed very imperfectly in this manner, because it cools too quickly.

ARTICLE VI.

Of the combustibles employed in glass-works.

Two kinds of combustibles are used in glass-works: wood and coals.

The employment of the latter is very advantageous, but it colours the glass by producing a fuliginous matter which is deposited upon the melted mass, and tinges it of a yellow hue. When we wish to make a clear or crystal glass, therefore, we must take the precaution of covering the pots, to which only one aperture must be left, corresponding with the working-hole; this is called working with *covered pots*.

When wood is employed, it must be care-

ily tried: the flux, in this case, is easier, and the work expensed. Elm, beech, and oak, are the three best woods for a melting-furnace. The resinous woods give out too much smoke.

It requires an active and intelligent person to manage the fire of a glass-house: care must be taken neither to choke it with too much fuel, or to let the heat fall off. It must be fed by renewing the fuel in small quantities at a time, and at short intervals.

The weight of clear glass to that of water, is :: 13 : 10. That of argl and alkali :: 25 : 10. That of lime and alkali :: 27 : 10. The metallic oxides add to its gravity.

CHAPTER III.

Of the combinations of the metals with each other, or metallic alloys.

OF all the mineral substances, those which nature presents to us in the most isolated manner, are the metals: and although we meet with some of them naturally united with others, we may lay it down as a principle, that they are every where found *per se*; and that the principal substances united or combined with them, are sulphur and oxygen.

But as soon as the metals are extracted or freed from their matrices or *mineralizators*; as soon as they are brought, by the processes of art, to the metallic state, we may unite them, and form by the combination or alloy of several, compounds which enrich the arts.

It is this reciprocal fusion or combination, this intimate penetration of two or more metals, that is called alloying. The appellation of *amalgam* is confined to the solutions alone of the metals by mercury.

But in order to form an alloy, there must be a concurrence of several circumstances. The first requisite is, that one of the metals is ~~and~~ must be in a state of fusion; and that which is fused, or which enter first into a state of fusion when we alloy two or more metals, may be regarded as the dissolver of the others: the second requisite is, that the metals should be in the metallic state; for if they are oxidized, they refuse to enter into any alloy.

It is easy to conceive, that all the metals are not alloyed with the same facility: this operation, as well as all the other chemical operations, obeys the particular laws of the very different affinities exercised by the metals among each other.

There are some metals which art has not yet been able to alloy: they refuse all penetration; they shrink from each other, if we may use the expression, while there are others which it is sufficient to put in immediate contact, in order to form a combination and an alloy: Mercury is an example of this kind.

A very natural conclusion flows from these principles: by alloying, we form a body, *sui*

genesis, the properties of which can neither be foreseen nor deduced, from the nature of the elements which constitute it : this proves that alloys are true combinations, and not pure solutions nor simple mixtures, as might be supposed.

The examination and comparison of the principal known alloys, present to us almost every where the following characters, which we may regard as corollaries that may be drawn from the facts which alloys present to us :

1st, The ductibility of the alloy is always less than that of the component parts.

2d, The specific gravity of an alloy is rarely a mean term between those of metals united. Glauber and Becher have remarked, that the specific gravities of the alloys of metals differed essentially from the comparative gravity of their metallic elements.

3d, Fusibility, in its turn, presents great variations ; but in general, alloys are more fusible than any of the metals separately which compose them.

4th, The hardness of the alloy is generally greater than that of the metals composing it ; I say, generally, because the amalgams, with

mercury, seem to be an exception to this general rule.

5th, The fixity of the metals is modified in these combinations, and becomes in general more intense. Arsenic, which is so volatile when by itself, makes a strong resistance to volatilization when it is alloyed with platina or other metals.

6th, Every alloy displays colours that are no longer the combination of colours belonging to the metals alloyed. They are generally brighter.

We should therefore rank the alloys in the class of compounds, the properties of which do not rigorously flow from the known characters of the metals which constitute them : an alloy is therefore a composition, or a new combination, the elements of which are the metals.

The difference between the saline combinations and the metallic alloys is this ; in the latter there is not a point of saturation so well marked as in the former ; and the compound always preserves the characteristic qualities of the constituent principles ; while in the salts, there is a saturation of the contrary and dis-

cordant properties of the elements, and the produce of the combination has no longer any of the characters of the acids and alkalis which form it.

The reciprocal affinity among the metals, to which the phenomena of alloys must be referred, is so strong in several cases, that it is sufficient to place the metals in contact, in order to produce an alloy when one of the metals is in a fluid state.

In several cases, metallic plates are applied to the well-polished surfaces of other metals, in order to produce an adhesion, which is equivalent to an alloy, because it chiefly depends upon the respective affinity of the two metals.

We shall not fatigue our readers by detailing all that has been published by chemists upon alloys; we shall confine ourselves to a few extracts from their works, and to a detail of the daily practices in the arts, which will embrace every thing of interest to society.

Among the great number of alloys, the uses of some of them are very extensive, and of these in particular we shall speak in the following articles.

SECTION I.

Of the alloy of copper with arsenic—(white copper).

Of all the metals, copper is the most susceptible of contracting alloys; and it is this kind of prostitution with most of the metallic substances, that acquired it the name of *Venus*, among the adepts.

Arsenic forms a whitish and very brittle alloy with copper. We may form this alloy directly, either by the fusion of arsenic with copper, or by the fusion of the latter metal with the arseniate of potash.

But although we employ these two substances in equal proportions, it is very rare if the colour of either of them completely disappears; the alloy always retaining a copper coloured tinge.

In order to free the alloy completely from colour, the fusion must be repeated, employing the same proportion four or five times. The alloy is then white like silver, without ceasing however to be brittle.

If the arsenic is evaporated by a proper

heat, the copper resumes its ductility, and nevertheless preserves its white colour. When the operation is well performed, we may, on the first glance, mistake white copper for silver; but it is easy to ascertain the difference, from the properties inherent to the two metals.

White copper is employed in the manufacture of a great number of trinkets and household utensils, such as candlesticks, tea-pots, coffee-pots, &c.

SECTION II.

Of the alloy of copper with zinc—(yellow copper, brass, pinchbeck, Manheim gold, prince Robert's metal, tinning by means of zinc).

The alloy of zinc and copper is very easily made: the different proportions between these two constituent principles make such a difference in the colour and quality of the alloy, that particular names have been given to each of these combinations.

The alloy of these two metals is very duc-

tile; besides, it is not easily oxydated: and these two properties have so much multiplied its uses in the arts, that there is no substance more employed or more useful.

This alloy is so ductile, particularly when slightly heated, that it may be drawn out into very small wires. It is more ductile in the wire-drawing machine than under the hammer: if it is beat with the hammer when heated, it rolls up, or is reduced to powder. It preserves, in these respects, the principal characters of zinc.

The alloy of copper and zinc may be produced by the direct fusion of the two metals. M. de Saussure has proposed the melting of the copper in a crucible of plumbago, and that the zinc should be afterwards thrown into it, wrapt in paper: the whole is covered with phosphoric glass; the alloy is run out and sprinkled with phosphoric glass before it hardens. Care must be taken not to add the zinc while the copper is boiling up.

But in the workshops where it is made for commerce, calcined ores of zinc are used, particularly what is called *calamine*.

Of all the manufactories of brass, in Sweden,

that of Norkioping, in East Gothland, is the most considerable ; it contains four founderies, in each of which there are four furnaces, with eight crucibles in each, which are drawn out every 12 hours, in order to melt their contents into tablets. Each tablet weighs 540 pounds Swedish. The calamine is brought from Silesia, Poland, Hungary, and sometimes from the country of Limbourg.

The mines of calamine in Derbyshire, in England, and these of Limbourg, supply with calamine almost all the brass-works in Europe. In the neighbourhood of Warksworth, and Bonsall in Derbyshire, a great quantity of calamine is found in narrow seams at a small depth ; it is often mixed with the lead ore, which alters its quality. Several kinds of it are known there : the brown, the yellow, and a kind which is almost entirely white.

As the seams are on different estates, those who work them sell the calamine to a company, who after having cleaned it, and reduced it to pieces of the size of a nut, roast it in a reverberating furnace. The fire continues five or six hours, and they operate upon 10 or 12 hundred weight at once. The large pieces

are separated, and the small ones are passed through a sieve; the produce is washed in German boxes. The calamine is afterwards dried; after this, it is ground in a mill; and in this state it is sold: the principal demand for it is at Birmingham, for the different brass manufactories there.

The manufactories of brass established at Graslitz, in Bohemia; Rubisch, in Voigtland; at Achewrain, near Brialegge, in the Tyrol; at Cheadle, in Staffordshire, in England; and at Stolberg, in Juliers, in the department de la Roër, present very little difference in the processes adopted at these places. It is calcined calamine and charcoal which every where forms the cement in which the plates of copper are put; there is no difference, except in some modifications in the construction of the furnaces, the form and capacity of the crucibles, the management of the fire, &c. We shall therefore content ourselves with describing the process followed in the country of Juliers.

In the commune of Stolberg, two leagues from Aix-la-Chapelle, there are several manufactories of brass. There were 38, before

the revolution which united that country to France.

The copper they employ in these works comes from Norway, Hungary, Sweden, the Levant, and Cornwall, in England.

The calamine they use is extracted from the Vielle-Montagne, near Aix-la-Chapelle. It is also brought from the territory of Cornely-Mouster, near Stolberg.

Forty pounds of red copper are mixed with 65 pounds of calcined calamine in powder, with double the volume of pulverized charcoal.

Crucibles are filled with this mixture, and placed in the furnaces in two rows.

A violent fire is kept up for 12 hours, after which the melted metal is cast in sand.

The brass obtained by this first operation is coarse, unequal, and brittle.

It is refined as follows :

They place in the crucible a layer of calamine and charcoal, mixed in the above proportions ; a layer of brass is placed above ; a second layer of cement, and a second of brass, and so on alternately until the crucible is filled.

The matter is then heated for twelve hours,

and it is then cast upon masses of granite, previously heated, and the surface of which is rubbed over with cow-dung. The breadth and thickness of these plates are determined by the help of bars of iron, more or less thick, which are kept down by means of another block of granite placed above, and which may be raised by a pully.

Forty pounds of copper give from 55 to 56 pounds of brass. A part of this brass is intended for the wire-drawers : for this purpose, it is cut into threads with a pair of large scissors ; these threads of brass are prepared for the operation of the wire-drawing machine, by placing them in heaps in a furnace, and soaking them in a bath of tallow.

Brass wire is used for the chords of musical instruments, sieves, pins, &c.

In the Swedish manufactories, the plates of brass intended for wire-drawing are passed several times through the rolling-press, and re-melted each time in a reverberating furnace. They are beat upon the anvil by a little hammer, which is moved by water, and afterwards cut with a pair of hand-scissors, into slips proper for passing through the wire-drawing machine.

The mines of Rammelsberg, in the Lower Hartz, furnish so great a quantity of cadmia (oxyde of zinc), which adheres to the sides of the furnace, that it is employed instead of calamine for converting copper into brass.

Gellert published a process for making brass with blende (sulphuret of zinc); but this brass was brittle, and was not of a good colour. Messrs. Dufamel and Jars took up this method, and obtained fine brass by employing calcined blende only. I was convinced by my own experience, that when the blende was not previously freed of all the sulphur it contains, the brass was black and brittle.

Brass, exposed to a violent fire, is decomposed; the zinc burns, and is volatilized, and the copper only remains.

We may separate the zinc from the copper, by dissolving brass in the nitric acid, and precipitating by caustic alkali, which dissolves the oxyde of zinc, and does not affect the oxyde of copper.

By melting yellow copper in various proportions with red copper, some ductile alloys result, the colours of which approach more or less to that of gold: these alloys have been

called Manheim gold, pinchbeck, prince Robert's metal, &c.

Equal parts of brass and red copper form a ductile metal, of the colour of gold, and pale.

Three-fifths of red copper with two-fifths of yellow copper, yield an alloy, the colour of which may be confounded with that of gold.

One part of yellow copper and two of red copper, give a deeper gold colour.

If, in place of employing yellow copper, zinc is used, and alloyed by fusion with copper, we may also form Manheim gold. In the latter case, we must cover the two melted metals with a layer of charcoal, for the purpose of preventing the loss of a great part of the zinc, and also in order to facilitate the combination. The most advantageous proportion for operating this composition is, to employ one part of zinc and four of red copper; the mixture is afterwards covered with charcoal in powder, and melted.

The facility with which zinc combines with copper, has suggested the idea of substituting it for tin in the tinning of copper vessels; and it results from the labours of Malouin, that this semi-metal spreads more equally over cop-

per than tin does, that it adheres more strongly, and that it flows with greater difficulty on the application of intense heat.

It has been objected, that the vegetable acids would dissolve it, and form salts which might be injurious to health. But M. Laplanche has dissipated all the fears that might be entertained on this head, by proving, from experiments made upon himself, that the salts of zinc, taken in a much stronger dose than could be contained in any food cooked in vessels tinned with zinc, were not at all dangerous.

The specific gravity of red copper being, to that of water, as 77.880 : 10.000 ; that of yellow copper passed through the wire-drawing press, is 88.755 ; the cubic foot would therefore weigh 621 pounds 7 ounces 7 drachms 26 grains ; and that of red copper, 545 pounds 2 ounces 4 drachms 35 grains.

The specific gravity of yellow copper, melted, is 83.958 ; the cubic foot would weigh therefore 587 pounds 11 ounces 2 drachms 26 grains.

Yellow copper is heavier, therefore, than red copper, and the pressure of the wire-press

increases the density of the former from a fifth to a seventh, while that of red copper only gains an eighth. It results from these facts, 1st, that the specific gravity of the alloy exceeds that of the two metals which form it; 2d, that the specific gravity increases by pressure.

We may therefore conclude, that in alloying there is a penetration and formation of a new compound, the properties of which cannot be inferred from the knowledge of the properties of the elements which form it.

SECTION III.

Of the alloy of copper with tin—(Bronze, bell or gun metal—tinned copper).

The alloy of these two metals forms either bell-metal or bronze, according as the tin is in a stronger or weaker proportion.

In general, 75 parts of red copper, melted with 25 of tin, form bell-metal.

When pieces of artillery are made, the copper is employed in a stronger proportion, in order to render the alloy less brittle.

Zinc, antimony, and other metals, are

sometimes added ; but these additions seem to be useless. Bell-makers have sometimes abused vulgar credulity, by pretending that they added a certain quantity of silver to the alloy, in order to render it more sonorous ; but they are better acquainted with business than to employ any of that commodity in the operation.

The alloy of copper and tin presents the following properties :

1st, It is more sonorous than any of the metals employed.

2d, It is harder than any of them, taken separately.

3d, It is more fusible than copper, and much less so than tin.

4th, It is less capable of being oxydated, and less ductile, than either of these two metals.

Pærner has remarked on this subject, that much copper and little tin yield a malleable metal, as well as plenty of tin and little copper ; but that when the two metals are alloyed from eight to ten parts of copper to one of tin, brittle alloys are obtained. This brittleness

diminishes both above and below these proportions.

This alloy has a greater specific gravity than that which would result from the combination of their particular gravities. Macquer observed, that two ounces of alloy, composed of four-fifths of a very pure red copper, and one-fifth of equally pure tin, have seven grains and one-tenth more specific gravity than the same quantity of these metals not alloyed would have.

Tillet observed, that the colour of copper disappeared upon its being alloyed by one-fourth of tin; and we cannot reasonably attribute this phenomenon to any thing else than to the intimate penetration or combination of the two metals.

Tin adheres to copper, and forms a coating upon it, which preserves it from oxydation, and from the corrosive action of the acids, salts, oils, &c.; and by means of tinning, we have succeeded in appropriating copper utensils to the cooking of our victuals.

To tin a copper vessel, therefore, is to cover its surface with tin.

The theory of tinning is founded upon some simple principles, the knowledge of which may throw a great light upon the art.

The first principle upon which the certainty of a good coating of tin depends, in order that the two metals may adhere together well, is, that both should be in the metallic state.

It follows from this fundamental truth, that the operation previous to the application of the tin, should consist in cleaning and polishing the surface of the copper, so that there be no vestige whatever of oxydation, and that it should every where present the *facies metallica*.

This is effected by scraping the surface strongly with iron tools, or by corroding it by acids, which dissolve the oxyde that covers it.

As soon as this operation is done, the tin is melted in the vessel we wish to tin, and placed upon lighted coals, in order to keep it sufficiently heated; and by the help of old linen rags, or hands of tow, the melted metal is spread over the interior surface of the vessel. Some charry bodies are added, such as resins, in order to prevent or destroy the oxydation which the heat facilitates. We may substitute muriate of ammonia (*sal ammoniac*), or

any of the oily or greasy bodies, instead of the resins. The muriate of ammonia has one advantage over the rest; being provided with a little soot, which it had acquired in the sublimation, and besides possessing a very decided corrosive virtue, it presents at one and the same time the property of scraping, as it were, the surface of the copper, and that of opposing oxydation: on this double property of sal ammoniac is founded the preference given it by workmen. We may also deduce from it the reason of the difference which all artists make between sal ammoniac blackened by soot, and sal ammoniac bleached by a second sublimation: the former is preferred for tinning; the second for dyeing: because, in the first case, a body is wanted which both cleanses and prevents oxydation; while in the last, a pure and colourless salt only is wanted.

In order that tinning may combine all the advantages to be expected from it, it must completely cover the copper upon which it is applied, in order to preserve that metal from the corrosive action of the salts, oils, and greasy substances. Tinning, when carefully managed, presents this advantage; but it is

attended with the inconvenience of melting at a moderate heat ; this is the reason why metallurgists have endeavoured to supply its place by substituting zinc.

SECTION IV.

Of the alloy of tin with iron—(Tinned iron, tin).

Iron rusts easily ; and this inconvenience would considerably limit its uses, if a contrivance had not been devised to remedy it, by covering the surfaces of iron with a coating of tin. It then bears the name of *tinned iron*, or *tin*, when it is sold in sheets.

In order to tin iron, the same precautions must be taken as in tinning copper, *i. e.* to clear and scrape the surface of the metal well, and to prevent carefully the oxydation of the surfaces at the moment they are covered with the coat of tin. These results are obtained by scouring the plates of iron with stone, and soaking them in water acidulated by the farina of rye having been fermented in it. They are then scoured a second time ; after this they

are wiped and rubbed very hard, and exposed in a very warm place.

There are some iron utensils which can only be scoured by the file : there are others, and those by far the greater number, which are scoured with sal ammoniac. The manner of using this salt, varies in different workshops : in some they dissolve it in water, and soak the articles tinned in this solution. In others, they expose them to the fumes of sal ammonia, volatilized by projecting it upon burning coals. In others, they heat their iron articles, and rub them with sal ammoniac itself.

But in whatever manner the iron is scoured, it is sufficient afterwards, in order to tin it, to plunge it in a bath of tin, and to repeat the dipping until the scoured surfaces are covered with a well-adhering coat of this metal.

It is in this manner that a great number of things are tinned ; such as bridle-bits, stirrups, buckles for harness, &c. But when sheets of tinned iron are prepared for commerce, a process is used, which although very little different from that we have described, ought not to be confounded with it, without some detail of it.

We shall confine ourselves, in giving an ex-

ample of this process, to describe it as practised in one of the principal manufactories of Bohemia, between Henricsgrun and Graslitz.

They begin, as in every other place, by reducing into sheets, by means of the hammer, the iron to be tinned. The rolling-press may be used instead of the hammer; or at least the operation may be finished by the rolling-press, and by this means we shall have a flatter and more equal surface.

Afterwards, in order to scour the sheets of hammered or black iron, and to dispose them to receive the tinning, there is an arched oven, in the middle of which there is kept up a constant fire of charcoal. All round, are hogsheds full of water, acidulated by rye having been fermented in it: 1154 cubic inches of farina are placed in each cask, and the water which dilutes it soon becomes sour. The heat of the oven is so great, that one cannot long continue in it.

Three hundred sheets are placed in each hogshed: they are packed vertically: they remain there 24 hours, after which they are plunged in a fresh quantity of acidulated water, made by the farina, as before. They remain

there 24 hours also, and they are taken out to put them into a very old lixivium, in which a hat-full of farina is thrown every fifteen days : thus the sheets to be tinned pass thrice 24 hours in all in the oven.

When they are brought out of the oven, they are put in hogsheads full of clean water, where they lie until they are cleaned, which is done by sand and water until there are no more black spots to be seen.

They are again put in water, where they are kept until they are tinned.

The tinning, properly so called, is conducted in the following manner : 18 hundred weight of tin are melted in an iron cauldron : when the tin is well melted, a little tallow is put upon the surface, and a little clean water is thrown in, which produces a boiling up, and occasions a little froth. A hundred sheets of iron, completely scoured, are then brought : they are placed above the froth, and gradually introduced into the bath, holding them with pincers, and laying them flat upon the bottom : a hundred sheets more are brought, and introduced in the same manner : they are left to soak for a quarter of an hour ; the tin is well

stirred with a stick ; the tallow and water are taken off, and poured into an earthen pan ; the leaves are then drawn out one by one, with the same pincers, and immediately placed upon two bars of iron, where they are supported by pegs.

A workman then takes the leaves, one by one, soaks them in a part of the cauldron which has been formed, and almost isolated from the rest of the mass, by means of a plate of iron inserted into it vertically : he immediately draws them out, and carries them to an iron-grating like the former : here it is that they are allowed to drip.

A woman then takes them one by one, cleans them with a piece of cloth, and rubs them with saw-dust.

The tin which has dropped from them is returned into the cauldron ; tallow is placed above it, and water thrown upon the whole. Care must be taken never to allow the cauldron to be empty.

The sheets of tinned iron are then taken near a furnace, where they are kept warm : a woman then rubs them with bran ; another

repeats the same operation : these women have a piece of cloth in each hand ; and a third finishes the operation by cleaning them with a finer cloth.

Two pounds of copper are generally added for every 140 pounds of tin.

When the tin is too hot, the colour of the tinning is yellow ; and when it is not hot enough, too much tin adheres to the sheets.

As the tinning is thicker towards the edges of the sheets, where the tin has dropped, when they are placed on the ground upon taking them out of the bath, this inequality may be corrected in two ways : 1st, by putting a little lighted charcoal under these plates, in order to melt the tin which is in excess upon the edges ; 2d, by soaking the thickest edge in a small cauldron, in which there is melted tin, and rubbing with a mop, in order to take off that which is superabundant upon the sides.

When the tinning is finished, 30 or 40 sheets are put together ; they are beat above and below, with a flat hammer, upon a large piece of wood, and by this means their sur-

faces are smoothed, and they are fastened together. They are folded a little in the middle, in order to give them the shape of barrels.

A pound of tallow is used for 300 sheets and 14 pounds of tin, when the sheets are small, that is to say, about 11 inches 2 lines long, by 8 inches and an half broad.

SECTION V.

Of the alloy of tin with mercury—(silvering of looking-glasses).

Mercury dissolves tin with such facility, that it is only requisite to bring them into contact, in order to produce an amalgam: a stick of tin, dipped by one end in a capsule containing mercury, sucks up the mercury, is penetrated with it, and in a short time the mercury rises to the other end of the stick, so as to form a very brittle alloy through all its length.

It is this great affinity between these two metals that has caused them to be used in tinning or silvering looking-glasses, *i. e.* to give them the property of reflecting objects with neatness and vivacity.

In order to silver a glass, previously well polished and prepared by the common processes, we begin by cleaning it with lixivated and well-sifted ashes : it is rubbed with flannel, and afterwards wiped with a very clean cloth. In order that the amalgam may adhere all over the glass, and, in a word that, the glass may be without any defect, in point of silvering, the surface must be very clean, without dust or spot of grease, oil or wax.

We afterwards take a sheet of tinfoil, as thin as paper, and a roll is made of it, in order that it may be more easily handled. This roll is taken to a well-polished marble, the surface of which is larger than that of the tinfoil when rolled out. This marble or stone is supported on a table, round which there is a gutter for receiving the superabundant mercury. Some notches are made in this gutter, in order to allow the excess of metal to flow into wooden buckets, which are placed all round for that purpose. The table is mounted so as to form a perfect level, and so as to be inclined at pleasure, several inches, by means of a hinge.

The tinfoil is unrolled, and applied upon the stone with a ruler polished and rounded on the

side which presses upon the tin, in order to remove the swellings or ridges which may be formed on it.

This sheet of tinfoil is first polished by rubbing it with a pallet soaked in mercury.

A great deal of mercury is afterwards spread upon the tinfoil, and a stripe of paper is glued upon the lower edge of the leaf.

When the whole is thus arranged, the glass is brought in, supported upon two bars of wood fixed upon the edge of the table: the extremity of it is applied upon the bed of tin and mercury, and it is made to slide horizontally, so that it cuts into the bed of mercury. The quicksilver retained by the stripe of paper glued to the lower edge, escapes by the two sides.

They then place upon the glass, and at distances nearly equal, several wooden porringers full of coarse lead: they sometimes use for this purpose, plates of lead, which are applied upon flannel, in order not to scratch the glass. These weights lie for six or eight hours, so that all the parts of the surface of the glass may contract an intimate adherence with the amalgam.

As soon as the weights are taken off, the glass is carried to another wooden table, well planed, where it is placed upside down. It is held by hooks, that it may not fall off when the table is inclined.

It is left four-and-twenty hours in this horizontal position; the table is then sloped six inches upon one of its angles only, in order to allow the mercury to drip off. It is left in this state 24 hours also, without touching it; and every 24 hours the table is sloped six inches, until the glass is perfectly perpendicular.

It is placed against the wall, always supported upon an angle, where it is also left some time in order that all the mercury which is not in solid amalgam may flow off.

The tinning of glass is not so adhesive as that of the metals; in the former case, there is only an application or juxta-position of a very close alloy upon a surface of glass, with which the metal has not a very sensible affinity; while, in the tinning of the metals, there is an affinity, a dissolution and a penetration; so that in order to separate two metallic plates united by tinning, not only is it necessary to

overcome the weight of the air, but also the force of affinity, which out of the two bodies forms one only ; in a word, the new body formed must be torn to pieces, in order to separate its elements.

SECTION VI.

Of the alloy of gold with mercury.

In order to amalgamate gold with mercury, it is only necessary to place them in contact : the gold becomes white in a moment, the mercury loses its fluidity, and in a short time the mercury dissolves the gold, and the amalgam forms a brittle mass, more or less fluid according to the proportions.

The most common amalgam. of gold with mercury is made as follows : they place in a marble mortar, one part of gold in leaves, and seven of mercury ; the mixture is triturated with a glass pestle, until the gold has disappeared ; this amalgam is washed several times in warm water.

It is this dissolving virtue of mercury which has suggested the employment of it in ex-

tracting gold from its ores, and in order to free it from all the substances with which it may be mixed. This process for amalgamating is so much the surer, that gold, almost inoxidable in its nature, presents itself generally every where in the metallic state, so that it is sufficient to pound well the substances which contain it, and to mix it afterwards with mercury, in order to get all the gold these substances may contain.

The amalgam is generally made in troughs full of water, by means of mill-stones, which divide the substances, and the instant the amalgam is made, it is put into a distilling apparatus, in order to separate the mercury which is evaporated, from the gold, which remains fixed in the retort.

Frequently, previous to amalgamation, the substances containing the gold are washed, in order to separate the particles of earth, which, being lighter, are taken off by the water.

Mercury almost always serves as the intermedium for causing gold to act upon other metals, particularly upon copper, as we shall see in the following article.

SECTION VII.

Of the alloy of gold with copper—(gilding by fire, or upon the metals—or-molu.)

When we wish to gild a piece of copper, we always begin by preparing or scouring it well : for this purpose, it is rubbed with sand ; it is then soaked for some time in aqua-fortis weakened by a good deal of water, and reduced to what is called *second aqua-fortis*. The article is afterwards heated, and when it is properly warmed, leaves of gold are spread upon it with a pad of cotton : they are then polished with the blood-stone, or burnishing-stick.

This immediate application of two metallic surfaces, very smooth, and perfectly scoured, does not produce a very strong adhesion : this gilding, therefore, is not thought very solid ; and it is employed for such articles only as are little exposed to handling or friction.

Gilding in or-molu is infinitely more solid : here the mercury is the intermedium between the gold and the copper. In order to gild in

brightened and developed by burnishing, as usual.

This method of gilding is very economical : the ornaments upon fans, snuff-boxes, and other trinkets, are merely very thin scales of silver, gilded in this manner.

It has been proposed to apply gold upon the metals by means of ether, which takes up gold from aqua-regia : but in my opinion, this process makes but a very imperfect gilding, and I doubt much, if by this method we should ever succeed in covering with gold the surface of any metal whatever.

Gold also alloys with copper by fusion ; and this alloy is used, as a soldering, when the former precious metal is wrought upon. This alloy, though much harder, is more fusible. It is, nevertheless, on account of the hardness which gold assumes, when alloyed with a little copper, that this last metal is added to the gold of which trinkets, dishes, or pieces of money, are made. Copper also heightens the colour in gold, and a small quantity of it does not at all alter its ductility.

SECTION VIII.

Of the alloy of silver with copper—(plating by fire, or upon the metals).

In order to cover copper with a coat of silver, the metal is first scoured with the second aqua-fortis; it is then brightened up, by rubbing it with a pumice-stone. The article is again heated, and dipped, before it is completely cooled, in the aqua-fortis, so that we may hear a slight hissing at the moment of its immersion.

All these operations, besides completely scouring the article, give it certain small asperities, which dispose it to take up and retain, more efficaciously, the leaves of silver.

When the article is thus prepared, it is mounted upon an iron stalk, or upon a frame of the same metal, which serves to manage the article conveniently when in the fire. As soon as it is thus fixed, it is heated, or *blued*; and when it is blued, leaves of silver are applied to it; to this effect, we take two leaves

in the left hand with pincers, and they are rubbed on and burnished with the burnishing-stick, which is held in the other hand.

If the article is too much heated at some places, it may be perceived by a kind of black dust, which is formed at the surface, and which is taken off with a kind of brush made of small brass wires.

After the article has thus received two leaves of silver above each other, it is again heated, and four other leaves are laid on, which are rubbed on, like the first, with the burnisher. They continue to lay on four or six leaves at a time, to the number of from 20 to 60, according to the degree of beauty or solidity which is required.

The leaves of silver generally used, are six inches square. In order to finish the work, it is strongly polished with the burnisher.

When we wish a very solid and very beautiful coat of silver, the article is cut or scratched in the same manner as when it is to be gilded in *or-haché*; and copper, plated in this manner, gets the name of *argent-haché*.

The silver of all coinages, as well as that

used in making dishes, is alloyed with a little copper. The silver becomes less ductile in consequence, but it is harder and more elastic.

Silversmiths also use the alloy of silver and copper for soldering silver articles. This alloy is infinitely more fusible than the metal, which has suggested its employment. The existence of the copper is easily recognized by the property which the solderings have of becoming covered with verdigrise.

SECTION IX.

Of the alloy of lead with tin—(soldering of plumbers).

Lead alloys with tin very easily; and the alloy is more fusible than any of the two metals which constitute it. In general, one part of tin, melted with two of lead, forms the soldering used by plumbers. But by diminishing the proportion of lead, we form what is called *strong soldering*: we may also increase the proportion, which is peculiarly necessary when we wish to solder vessels for containing

acids; because lead is not so easily corroded or dissolved as tin.

Utensils of tin or pewter are rarely free from an alloy of lead. The melters add it in a greater or less proportion, in order to diminish the price of the article they sell.

SECTION X.

Of the alloy of lead with antimony—(type-metal).

Antimony gives an additional hardness to all the metals with which it is alloyed.

When we melt antimony with lead, it communicates to it so much the more hardness as the proportion of it is greater.

It is the alloy of these two metals which forms printing-types: all the trials I ever made upon this composition, presented me with an alloy of 80 parts of lead, and 20 of antimony, as being the most perfect composition: a greater proportion of antimony renders the alloy too hard, too dry and brittle; a less proportion renders it too soft.

Gmelin has made a long course of experiments upon the combination of antimony with lead, whence he draws the following conclusions :

1st, Equal parts of these two metals form a porous alloy, which crumbles under the hammer.

2d, One part of antimony and two of lead, produce a more compact, and very brittle metal.

3d, One part of antimony and three of lead, give a metal harder than lead, and malleable.

4th, One part of antimony, and eight of lead, yield an alloy harder, and more fusible than lead, but malleable.

5th, One part of antimony and 12 of lead, form a hard, thick alloy, susceptible of being beat into sheets.

SECTION XI.

Of the alloy of lead with zinc.

Gmelin alloyed lead with zinc, and he was convinced that lead thus acquires brilliancy and hardness.

• In order to prevent the zinc from taking flame, when it is thrown upon melted lead, tallow is put into the crucible at the same time with the zinc, and the crucible is withdrawn from the fire as soon as we see that the zinc is melted.

• A great deal of zinc alloyed with lead, yields a metal of a leafy texture: it is harder than lead, and is very malleable: it is at the same time of a very shining appearance.

Two parts of zinc and one of lead, form a ductile, supple, and very hard alloy.

Equal parts of lead and zinc, produce an alloy very susceptible of polish, hard and sonorous.

The alloy of one part of zinc to eight of lead, is similar to lead, but it is harder, more

sonorous, more malleable, and more susceptible of polish.

In general, zinc always gives lustre, hardness, and a sonorous property to lead, in whatever proportions it is alloyed with that metal.

SECTION XII.

Of the alloy of mercury with tin and zinc.

Kien Mayer has made known the following amalgam composed of two parts of mercury, one of zinc, and one of tin. The tin and zinc are melted; they are afterwards mixed with mercury; the mixture is shaken in a wooden box, the inner surfaces of which are coated with whitening; and the mixture is reduced to a fine powder.

This powder is employed, either by itself or incorporated with grease, for rubbing the cushions of the electrical machine: its effect is wonderful.

SECTION XIII.

Of the alloy of copper with silver and mercury.

Melt and granulate equal parts of silver and copper, and distil them with muriate of mercury.

The mercury passes over into the receiver : what remains is put into a crucible and melted : iron-filings are projected upon it, and the mixture is kept a long time in fusion.

This alloy is very sonorous, white like silver, and very ductile.

SECTION XIV.

Of the alloy of platina with copper and tin.

M. Rochoa, by alloying platina with copper and tin, has made reflecting mirrors for telescopes of it, the effect of which far surpasses those which have been hitherto made with steel.

This superiority is owing to the density and inalterability of the platina.

SECTION XV.

Of the alloy of bismuth with lead and tin.

Newton, Muschenbrock, and Homberg, have observed, that these three metals form a very fusible alloy.

But Darcet has discovered proportions which render this alloy so fusible, that it melts in water heated to a degree lower than that of ebullition. These proportions are eight parts of bismuth, five of lead, and three of tin.

CHAPTER IV.

Of the separation of the metals.

FOR a long time, the denomination of *parting* has been given to the operation by which we separate gold and silver from each other : but as the alloys among the different metals are frequently presented to us by nature and art ; and as it is important to know the method of operating their separation, we shall generalize the word *parting*, by applying it to all the operations which produce these separations.

In this chapter we shall only speak of the processes adopted in the workshops of the arts ; and I shall pass over in silence, all the chemical methods which may be employed by an intelligent analyser, in order to discover and separate some atoms of various metals confounded in one mineral mass. This operation belongs to analysis, properly so called, and does not form a daily and common process in commerce.

As all the metals do not act in the same manner, either with the acids or with oxygen; and as their fixity in the fire, and their degrees of fusibility vary infinitely, we may take advantage of these natural properties to separate them from their alloys, and I think I may consequently reduce to the number of five, all the processes which art employs in order to produce the separation of the metals.

SECTION I.

Of the separation of the metals by means of the acids.

We have already observed, that all the acids do not act in the same manner upon all the metals: there are metallic bodies which are soluble in a very small number of acids only, while others are soluble in almost all of them.

We may therefore take advantage of this known property, in order to separate from a metallic alloy certain metals, without touching the others in that alloy.

But, in order that the action of the acid employed may be free, and take up to the last

atom of the metal it dissolves, the metals must be alloyed in convenient proportion ; otherwise, that which is susceptible of being dissolved, might be in so weak a proportion as to be deprived of the action of the acid entirely. To prevent this inconvenience, it is usual to ascertain, previous to the operation of parting, that the metals are alloyed in a proper proportion ; or to bring them to such proportion, by the addition of a part of the soluble metal, if the proportions are not already as they ought to be.

It is also indispensably necessary to employ pure acids ; otherwise their effect could not be depended on, nor would the operation be rigorous.

When the acid does not act very energetically upon the metal, it is useful—1st, to divide the alloy, so as to multiply the points of contact, which may be done by reducing it into very thin plates, into powder, or by granulating it ; 2d, to assist the effect of the acid by heat.

The most common operation of parting, is that by which gold is separated from silver, copper, or other metals with which it may be

alloyed. If, for instance, we wish to judge of the value of gold, we alloy the gold to be assayed with four parts of pure silver, which is called *quartation*. We may even form this alloy as suggested by M. Sage, with two parts and a half of silver to one of gold.

The law of France directs us to operate upon 24 grains of gold: it is admitted at 12 grains and rejected at six, on account of the difficulty of appreciating the divisions which result from these small quantities.

The two metals are placed in a plate of lead, free from all alloy, and four times the weight of the two metals: we proceed to cupellation in the usual way: the lead is dissipated in fumes, and is partly absorbed into the porous bodies of the cupell. After the lead disappears, there remains a metallic button only, which contains gold and silver. The separation of the lead has been thus effected; but it remains to separate the silver, still united to the gold, in order to ascertain what the latter has lost, and consequently what foreign bodies it contains.

For this purpose, the metallic button is flattened, laminated, and rolled up like a wafer:

it is then put into a small matrass, into which we pour six drachms of pure nitric acid, which, in reference to this operation, is called *aqua-fortis* for *parting*. This acid generally marks from 35 to 40 degrees in Baumé's areometer. As soon as the matrass is heated, the roll of metal becomes brown, the silver is dissolved, and in 15 minutes we decant the solution, and add one ounce of very pure acid, a little more concentrated than the former, in order to take up the portions of silver which may have escaped. We again decant in 15 or 20 minutes, and wash the roll in warm water; it is then dried in a crucible; carefully weighed; and we judge from the diminution of its primitive weight, of the quantity of foreign matter it contained. But in order to have terms of comparison, we suppose very pure gold as at 24 carats; we divide the carats into thirty two parts, so that if we have employed in the operation, 24 grains of alloyed gold, and if the produce afterwards only yields 22, we say that the title of the gold essayed is 22 carats; that is to say, there is one-twelfth of foreign matter in the gold which we have been essaying.

SECTION II.

Of the separation of the metals by oxydation.

All the metals have not the same affinity for oxygen: there are some which strongly resist oxydation, while others combine with oxygen with such facility, that it is troublesome to preserve them from its action.

There are metals, such as iron, which oxydate in the air; which decompose water and the acids, in order to seize upon their oxygen: there are others, for which the action of heat is necessary, such as lead and tin, which at the temperature of the atmosphere, preserve, with little alteration, their metallic lustre, while as soon as they are melted, they are covered with oxydes.

There are others, finally, which have so little affinity for oxygen, that fusion itself cannot produce oxydation: gold, silver, and platina, are of this number.

We may therefore profit by this constant and characteristic property, for separating certain metals from an alloy, without altering those

which we wish should be united to them, and from what we have remarked, it is possible to proceed to this separation in various ways: 1st, by the action of the air, assisted by heat; 2d, by the decomposition of the acids; 3d, by the application of an oxydated metal to another metal which can give up its oxygen to it.

When we wish to separate an almost inoxydable metal, such as gold, silver, or platina, from other very oxydable metals, it is only necessary to melt the alloy, and to keep it long enough at a degree of heat capable of oxydating completely the metals which are susceptible of it then. When the oxyde which is formed remains confounded with the unaltered metals, in this case it is separated by sifting (considering that it is almost always in powder), by scraping, and taking off the oxydated stratum as fast as it is formed; or rather, the oxyde volatilizes in fumes, as in the separation of the alloy of lead with silver and gold.

It may also happen that the metals alloyed may be oxydable at such different points that the same process of oxydation cannot separate them: but in this case, we have also the resource of profiting by the greater or less faci-

lity which these oxydes present to their reduction, in order to operate a separation, which was impossible by the first process resorted to: thus the alloy of tin and copper may be entirely oxydated by fusion; but this mixture of two oxydes being treated by the processes of reduction, the copper will flow in the state of metal, without the tin being revived.

The oxydation of the metals by the decomposition of the acids, is also of very great assistance in effecting the separation of the metals. For instance, we may decompose and disunite an alloy of lead and tin, or of tin and copper, by exposing it to the action of the nitric acid, which corrodes and oxydates all the metals, without dissolving the oxyde of tin, while it dissolves those of copper and lead.

There are cases where the acid dissolves one of the metals of the alloy, without touching the other: this always happens when an imperfect metal is alloyed with a perfect one: and it is in this manner that we treat the auriferous pyrites, the copper containing gold, &c.

SECTION III.

Of the separation of the metals by the action of other metals.

If one metal has more affinity for oxygen than another has, we may oxydate the one at the expence of the other, which resumes its metallic character on giving up its oxygen. The transferring of oxygen from one metal to another, is very marked in all cases where we precipitate one metal from a solution by means of another metal: thus copper precipitates silver and mercury from their solutions in the nitric acid; because, having more affinity for oxygen it takes it from these two metals, which afterwards appear in the metallic state, and it takes their place in the solution. It is in consequence of the same principle that iron precipitates copper; that tin precipitates the same metal; and that mercury precipitates silver, &c.

It also follows, from the difference of affinity which the various metals have for oxygen, that in the metallic alloys submitted to calci-

nation, there are interchanges of oxygen which restore to the metallic state the least oxydable metals.

SECTION IV.

Of the separation of the metals by their respective degrees of fusibility.

The very variable degrees of fusibility among the metals, supply us with the means of separating certain of these substances, by making them flow from their alloys by the application of different degrees of heat.

It is by this means we separate tin, lead, and bismuth from almost all their alloys, with the hard and refractory metals: but in all these cases, there must not be a great affinity among the metals alloyed; for if there were, the metal the most fusible would carry away the other, as we see in the alloys of lead and mercury with gold and silver.

Besides, where the ties of affinity are powerful, the metal that is most infusible, commu-

icates some degree of its infusibility to that which is alloyed with it, and it then flows with more difficulty than when by itself.

SECTION V.

Of the separating of the metals by sublimation.

There are some metals which are sublimed without being oxydated, such as mercury, gold, silver, &c.

There are others which volatilize, reducing themselves into the state of oxydes, as antimony, arsenic, zinc, &c.

Several of them are very fixed, both in the metallic state and state of oxyde, as copper, iron, and tin. This fixity must not be regarded, however, as absolute, since they are partly sublimed in the state of oxyde; but not completely enough to entitle us to place them among those of the second class.

This different manner of acting in the fire, presents us with an easy method of separating them when they are alloyed: if arsenic is

united with any metal, it is sufficient to expose the alloy to the fire, and we may see the arsenic escape in white fumes.

We may also separate zinc from copper, by bringing the alloy to a white heat, and provoking, by this means, the oxydation, combustion, and sublimation of the zinc.

Antimony and mercury may be separated from their alloys in the same manner.

It remains for us to furnish some practical examples of the various processes we have mentioned.

1st, It is by cupellation that we separate from silver all the metals which may be alloyed with it, with the exception of gold and platina.

In order to proceed to cupellation, we must weigh 36 grains of the silver we wish to essay, and envelop them in a piece of lead rolled up.

On the other hand, we must have small crucibles, made of the ashes of strongly calcined bones; these ashes must be very care-

fully washed, and well dried; small crucibles, or *cupells*, are afterwards formed in moulds, into which the ashes are forcibly squeezed, and weakly moistened, in order to give them a proper consistence.

When we use these small *cupells*, they are placed in a muffled furnace, surrounded with charcoal: a red-heat is made; and in this state we deposit the roll containing the essay, in the small cavity or depression which is in the middle of the *cupell*.

The alloy soon melts: we see the lead fume, and evaporate in the state of oxyde, at least the greater part of it; while, at the same time, another part is absorbed by the pores of the *cupell*. When all the lead has been evaporated or absorbed, a white button only remains in the bottom of the *cupell*; and this is what is known by the name of *pure, or cupelled silver*, when there is no gold in the alloy.

The loss of weight the silver suffers in this operation, answers to the quantity of foreign substances which were alloyed with it. It has been therefore supposed, that the purest silver was at 12 pennyweights, and each pennyweight is afterwards divided into 24 grains;

so that if the silver has lost half a pennyweight in the essay, we may conclude that the title of the silver is 11 pennyweights 12 grains.

2d, If we submit to the action of the nitric acid, an alloy of lead and tin, the acid oxidates the tin without dissolving it; while it dissolves the lead. The same thing happens when we treat with the same acid an alloy of tin and copper.

But if we expose to the same acid, very pure, an alloy of gold and copper, or of any other metal, the former is dissolved, and the latter remains untouched.

When copper, iron, zinc, and other metals very soluble in the acids, are alloyed with others which are less so, the weak acids take up the former, without touching the latter,

3d, In order to give a striking example of the separation of the metals, by the metals themselves, according to their different degrees of affinity for oxygen, we shall confine ourselves to detailing the processes proposed or practised for producing the separation of the copper in the alloy of bell-metal.

Seventy parts of copper, melted with 25 of tin, form the metal of which bells are made.

No metallic alloy is so generally in use as this one. At the dreadful period of the revolution, government thought of thus finding an abundant mine of copper for making their pieces of cannon; and almost at the same moment, Messrs. Pelletier, Fourcroy, Auguste Dizé, and Jeanety, suggested and executed processes for effecting the separation of this alloy.

All the processes may be reduced to that of oxydating the two metals which compose the alloy, by the atmospheric air, the nitrates, or manganese.

M. Fourcroy proposed adding to this melted metal, one-third of the same alloy oxydated, and to beat up the mixtures together with great care. In this case, the affinity of the oxygen being more decided for tin than for copper, it follows that the oxygen, already fixed upon the copper, abandons it, in order to act upon the tin, and the copper flows in the metallic state.

4th, When the copper contains a quantity of silver sufficient to admit of its being extracted,

we proceed as follows: 75 pounds of this alloy of copper and silver are melted with 275 of lead; this alloy is melted into loaves, which are placed in a furnace, and a degree of heat is given sufficient to melt the lead: this metal takes up the silver which it gets from the copper, so that nothing else is necessary than to cupell it, in order to extract the silver it contains. The copper, full of holes in consequence of the spaces left by the lead in melting, always preserves the primitive form of the loaves. But these loaves still retain a little lead, which may be extracted from them by a stronger heat.

CHAPTER V.

*Of the combinations of oxygen with the metals,
or the metallic oxydes.*

ONE of the principal characters of the metals is, their very decided affinity for oxygen: we may even regard this character as distinctive between the metallic and the earthy substances; for the latter do not appear to be at all susceptible of combining with oxygen.

Although all the metals have an affinity for oxygen, and all of them burn, when we facilitate this combination by a very high temperature, or lower the force of cohesion which unites the metallic elements, all are not combined in the same proportion with oxygen, nor with the same facility.

The force of cohesion is one of the first obstacles to the action of oxygen: we may overcome it, either by means of heat, which dilates the metals, and renders their molecules more accessible to the oxygen, or by the mixture or alloy of the metal with other metals:

it is thus that gold and silver, when amalgamated with mercury, may be oxydated at the temperature of the atmosphere.

Another property which modifies the affinity of metals for oxygen, is the volatility which some of them acquire upon being heated. A metal which liquefies, is a state very favourable to the combination; and it takes up, in this case, a determinate dose of oxygen: it also often acquires such a fixity, that if we expose the oxydes to a greater heat, oxygen is liberated, so that we may regard this state of oxydation as a tolerably constant term.

The oxydes formed in this manner have more fixity than the metals themselves. Thus the oxydes of mercury, antimony, zinc, and arsenic, when once formed, resist a heat capable of volatilizing the metals. This evinces, that there is a true combination between the metal and the oxygen, which fixes, condenses, and forms a new body.

If the metals that are susceptible of being volatilized, take such proportions of oxygen as may be regarded constant, it is not the same with the other metals, which are fixed in the

fire, and upon which we may graduate the oxydation, by subjecting them to a successive course of degrees of heat, so as to develop a series of colours, and to present a progressive increase in weight, by the fixation of the oxygen *.

The oxydes of the metals, however, which are susceptible of being volatilized, may take or lose oxygen by means of a more violent fire applied to the oxyde : M. Thenard varied the oxydation of antimony from 16 to 20 *per cent.* by exposing the oxyde to a varied heat ; Messrs.

* This gradual progress of oxydation proves, that the degrees of oxydation are well determined, and not numerous in the solutions by means of the acids. M. Pronst admits of no doubt on the subject ; and the difference of opinion between this experienced chemist and M. Berthollet, turns only upon the number of *fixed degrees*.

There are terms of oxydation which are fixed ; the intermediate degrees are merely stages where the oxyde rests only until we afford it the means of going farther. It is then a forced state, and cannot be regarded as a constant one. It must also be allowed, that were it otherwise, there would be nothing fixed in the saline combinations. It is in this sense we must understand the *pondus naturæ* of the celebrated Stahl.

Clement and Desormes were convinced, that the oxyde of zinc lost its oxygen by a strong heat, and assumed a yellow colour.

There is a determinate degree of heat, which is the most favorable to the oxydation of a metal: when we stop above or below it, the oxyde loses its oxygen by a too strong heat, and is not saturated with it at a too moderate heat. It seems that the degree proper for volatilization is that which produces the strongest oxydation in the volatile metals.

It is requisite therefore to determine with precision the different degrees of heat necessary for producing constant and invariable oxydations: experience has already furnished artists with certain principles upon which they prepare the various oxydes for sale: but their observations are not sufficiently confirmed; every thing is vague in their processes; we are therefore still under the necessity of manufacturing several essential products in a slovenly manner, such as the oxydes of lead, copper, and mercury. As a consequence of these principles we might learn why, upon varying the degree of heat, the oxydes are transferred from one colour to another: minium, for instance,

becomes red by losing a portion of its oxygen, on the application of a stronger heat; from a similar cause, the white of zinc passes to the yellow; the black of manganese to white; the red of iron to black, &c.

When we have arrived at the last term of oxydation, by the most proper degree of heat, we may still increase it, by applying to the oxyde already formed, a body which contains oxygen condensed, and adhering but slightly to the base upon which it is fixed: in this manner also, oxygen is added to the red oxyde of lead, by means of the oxy-muriatic acid and nitric acid. M. Thenard has proved, that by similar processes the oxyde of antimony sublimed, took 12 *per cent.* of more oxygen. M. Chenevix has produced the hyper-oxydation of mercury by the same means. A moderate heat only is requisite to liberate an excess of oxygen, and restore these oxydes to their primitive state.

By causing a concurrence of the two methods we have mentioned, we can transfer to the acid state such of the metallic oxydes as by their natural dispositions can receive a great proportion of oxygen. Thus 100 parts of arsenic

may receive, by common calcination, 33 of oxygen, according to M. Proust: but if we present to this oxyde the condensed oxygen, it takes up 20 parts more in weight, and develops all the characters of an acid. Iron may be charged with the same dose of oxygen, without contracting any acid property. The oxydes of chrome, molybdenum, and tungsten, easily assume the acid character, and have all the properties of it.

The metals which by themselves possess no very brilliant property, assume by oxydation the richest and most variegated shades. They are, in general, fixed enough in the fire, where most of them acquire a much greater brightness, which causes them to be employed as colouring principles in the varnish of earthenware; the enamel of white stone-ware, the covering of porcelain, and the colouring of glass.

We may oxydate the metals in various ways.

1st, It is sometimes sufficient to expose the metal to the air in order to produce its oxydation: iron, arsenic, manganese, and copper, are in this situation. Such is their affinity for

oxygen, that simple contact is sufficient to overcome the resistance opposed to the combination by the elasticity of the fluid, and the cohesion of the metal.

2d, We may determine the oxydation of several metals, and facilitate that of all of them, by raising their temperature: by this means we oxydate tin, lead, mercury, &c. when the metals can undergo a fusion without being volatilized, in this state they are better disposed for oxydation. This disposition of temperature, nevertheless, has boundaries; and if we exceed the point most favourable to oxydation, we de-oxydate the metal or vitrefy the oxyde.

3d, The combined action of air and water facilitates oxydation much: the metals are preserved from all rust or oxydation when kept in a dry place, when their surfaces are carefully rubbed; and particularly when they are protected from the contact of a damp atmosphere. In order to account for these effects, it is only necessary to recollect, that water dissolves and condenses a certain quantity of oxygen gas; and that the oxygen presented under this form is combined with so much the more facility,

that it has not to combat its elasticity any longer ; so that when we moisten a metal and expose it to the air, an intermedium of union is established between the air and the metal ; and when we place the metal in contact with a humid atmosphere, the oxygen is presented to it, at every instant, in solution in water, and in the most favourable dispositions to its combination.

It is to a similar cause that we may attribute the progress of oxydation obtained by sprinkling the metals with some acid, which of itself has not the property of being decomposed over the metal, at the temperature of the atmosphere : in this case, the oxygen, which is condensed in the liquid, oxydates the metal, and predisposes it to the dissolvent action of the acid : the oxydation is also here facilitated by the affinity exercised by the acid upon the metal, which necessarily diminishes the cohesion.

4th, Water alone may be decomposed over the metals, and produce their oxydation : but in this case, the temperature must be high. In this manner we may decompose water, by making it drop upon red-hot iron ; hydrogen

gas alone is liberated, and the oxygen remains in combination with the metal.

We may decompose water at a much lower temperature, by making it act, in concurrence with atmospheric air, upon a metal easily oxidated, such as iron: it is only necessary to present to this metal plenty of surfaces, and to present it in a large volume, so that the effect may be more sensible: this happens when we heap up moist iron-filings: the air then penetrates the whole mass, acts upon all the points, and determines, by its concretion over the iron, a heat which increases every moment, in consequence of the work of oxidation; the cohesion of the metal necessarily diminishes, which facilitates the decomposition of the water which moistens it, and we are soon convinced of the reality of this decomposition, when we smell the hydrogen gas which is liberated. The heat is sometimes carried so far, that an inflammation of the hydrogen, and a more rapid combustion of the mass, take place.

5th, The acids dissolved in water, and applied to a metal, facilitate the decomposition of this liquid, when, from their nature, they

cannot furnish oxygen to the metallic oxydation. This example is presented to us by the sulphuric and muriatic acids, &c. The powerful affinity which the radical of these oxydes has for oxygen, does not indeed admit of their abandoning a part of the acidifying principle in order to bring the metal to the state of oxyde, and to prepare it for being dissolved by that part of the acid which remains undecomposed; but they do not cease, notwithstanding, to exercise a power of solution upon the metal, which is strong enough to diminish the cohesion of the parts, and to facilitate the decomposition of the water, and the fixation of its oxygen. In proportion as the oxyde is formed, the acid is dissolved, and the heat produced, hastens and completes the operation. While the oxygen of the water is combined with the metal, its hydrogen escapes in the form of gas.

6th, Oxydation is often not produced, except by the decomposition of a portion of the acid which we cause to act upon the metal; but this only takes place with such acids whose oxygen adheres but slightly to the radical: such are the oxygenated nitric, and muriatic

acids. Thus, when we present one of these acids to a metallic substance, a portion of the oxygen is separated, in order to act upon the metal, which, reduced to the state of oxyde, is dissolved in the part of the acid which is not decomposed.

It even happens, in some cases, that the metal is oxydated without there being any solution ; in this case, the oxyde is precipitated as fast as it is formed ; and we may, by this method, attain almost complete decomposition of all the acid, and with a complete corrosion or oxydation of the metal.

7th, It sometimes happens that one acid alone neither oxydates nor dissolves a metal ; but by mixing them together in proper proportions, we produce both of these effects : for example, gold is insensible to the action of the nitric and muriatic acids separately, and it is dissolved in the mixture of these two acids ; because, in the latter case, the muriatic acid, which exercises its action upon the metal, weakens the force of cohesion between the molecules, and facilitates the action of the oxygen of the nitric acid, which produces the decomposition of this last, and the oxydation of the metal.

8th, Not only the acids, but the salts which have the acids for their bases, may oxydate the metals, provided their decomposition is assisted by the action of heat. Thus, if we mix zinc, or iron-filings, with oxygenated nitrates, or muriates, and, after having pounded the mixture, if we project it into red-hot crucibles, there will be a decomposition of the salts, and an oxydation, or combustion of the metals.

9th, The phenomena of the precipitation, by means of another metal, of a metal dissolved in an acid, have been improperly attributed to their respective affinities for the solvent. These phenomena all originate from the more or less strong affinity which the various metals have for oxygen; so that if, to the solution of a metal by an acid, we present a new metal which has more affinity for oxygen, that which is in solution will be precipitated in the metallic state, and the other will assume the place it occupied in the acid. This is what takes place when we precipitate copper by iron; silver and gold by copper, &c.

SECTION I.

Of the oxydes of arsenic—(arsenic, flowers of arsenic, arsenic acid).

What is called in commerce, *arsenic*, or *flowers of arsenic*, is a metallic oxyde.

This oxyde is extracted from the mines of cobalt in Bohemia and Saxony, by the calcination of the mineral: the oxyde is sublimated at a moderate heat, and is deposited upon the sides of a long spiral chimney or flue, in which the vapours are collected.

The plates or flakes of oxyde extracted from these chimnies and exposed to sale, are sometimes vitreous and of a yellowish colour: this vitreous oxyde is easily altered in the air, and becomes white, opaque, and pulverulent.

We also find oxyde of arsenic in its native state, in the mines we have mentioned, as well as in volcanic rubbish.

This oxyde is volatilized at a moderate heat: if we throw a pinch of it upon burning coals, it is elevated in a white fume, which exhales

a very marked smell of garlic: this smell forms one of the distinguishing characters of this oxyde, and does not admit of its being confounded with other substances, the appearance of which might deceive the eye at first sight.

The specific gravity of glass of arsenic is to that of water as 35,942 is to 10,000. The cubic inch weighs 2 pounds 2 drachms 35 grs.† and the cubic foot weighs 251 pounds 9 ounces 4 drachms and 2 grains.

The specific gravity of the crystallized oxyde is 24,775: the cubic inch weighs 1 ounce 4 drachms 61 grains; and the cubic foot, 173 pounds 6 ounces 6 drachms 29 grains.

The specific gravity of regulus of arsenic is 57,633. Boiling water dissolves 1-sixty-fourth of oxyde of arsenic. Water, at 12 degrees of temperature (Reaumur's thermometer) dissolves 1-eightieth.

The oxyde of arsenic is equally soluble in alcohol; but water and alcohol deposit, upon cooling, the oxyde which is in excess; and crystals are formed which appear to me to be very much elongated, tetrahedral pyramids.

The oxyde of arsenic is of little use in com-

merce ; it is used as a very active flux in glass-houses and in metallurgic works. I have observed, several times, that when the composition for making glass refused to enter into fusion, it was only requisite to throw into the bottom of the pots, and below the composition, three or four ounces of this oxyde, and to stir up the composition afterwards to produce an immediate fusion.

This oxyde may be alloyed with almost all the metals, which it renders very fusible ; we may separate it from all these alloys by heat, so that this oxyde may be considered as a valuable flux in many cases.

The oxyde of arsenic is used as a poison ; and for this purpose it is mixed with farina, fat, cheese, &c. or it may be dissolved in water, in order to poison rats and mice. But bad men have too often made it an instrument in the commission of crimes ; and all things considered, this metal is a direful gift to humanity. It were better that it should be sunk in everlasting oblivion, than produced in commerce, in order to be applied to a few limited purposes.

The oxyde of arsenic differs from the other

metallic oxydes in so much as it is soluble in water, and unites and alloys with the metals: the first of these qualities makes it resemble saline substances.

This oxyde is of the nature of those which are susceptible of taking a greater degree of oxydation, and of contracting all the character belonging to the acids.

The arsenic acid is made by distilling six parts of nitric acid over one of oxyde. It may also be made by distilling in the same manner, the oxy-muriatic acid. In all these cases, the acids are decomposed, and give up their oxygen to the oxyde, which passes into the state of arsenic acid.

By distilling equal parts of nitrate of potash and oxyde of arsenic, we obtain an almost incoercible nitrous acid, and a residue, the properties of which Macquer has perfectly developed by the name of *neutral arsenical salt*. It is an arseniate of potash, from which we may separate the arsenic acid, by means of sulphuric acid distilled above it at a strong heat.

Pelletier has suggested, that we should decompose by distillation the nitrate of ammonia,

by means of oxyde of arsenic ; there remains in the retort, an arseniate of ammonia, from which we may separate the alkali by a strong heat ; the residue is then a vitreous mass, strongly attracting humidity : it is then *pure arsenic acid*.

This acid is fixed in the fire ; but when dried by heat, if we expose it to the air, it attracts the humidity, and deliquesces.

The contact of a charry body, when heated, decomposes it, and oxyde of arsenic and carbonic acid are exhaled.

Hydrogen can also deprive it of its oxygen, as observed by M. Pelletier.

It is dissolved in two-thirds of its weight of water, at a heat of 12 degrees of Reaumur's thermometer.

M. Berthollet observed, that when this acid was strongly concentrated by the fire, it dissolved alumine.

Bergman thought he discovered, that this acid had more affinity for lime and magnesia than for soda and potash.

SECTION II.

Of the oxydes of cobalt—(zaffre, azure, blues).

The mines of cobalt are wrought at Joachimstahl, and Platten, in Bohemia, and at Schneeberg, in Saxony.

Upon the frontiers of Spain, in the Pyrenees, in the valley of Gisten, M. le comte de Beust wrought a cobalt mine, about the end of last century; and it is much to be desired, that these works, suspended in consequence of the war which broke out between France and Spain, should now resume their activity. It is the only establishment of this kind France can boast of: it was carried on for the fabrication of azure, and they have been fortunate enough to find, near the village of Juget, a quartz, interspersed with cobalt, where these two substances are naturally in the proportions requisite to form glass of azure.

In all these manufactories, after having picked the mineral, and carefully separated it from all foreign substances, as well stony as metallic, it

is put under the stampers in a dry state : the poorer sort of ore is broken under the hammer, and washed upon tablets, in order to carry off the stony particles.

In some mines, where the mineral of cobalt contains bismuth, this last metal is separated by exposing the mineral to a heat capable of melting it.

The mineral, when well prepared, is put into a reverberating furnace, where it is stirred often, in order to dissipate the arsenic and sulphur ; three or four hours are sufficient for this operation ; too much calcination renders the colour feeble, and the glass contains less quartz ; too little calcination, gives little colour, and of a bad quality.

After roasting, the oxyde of cobalt is pounded, sifted, and mixed with two or three parts of sand or quartz : it is in this state it is sold by the name of zaffre.

In Saxony, zaffre is made of the best cobalt, pulverized and roasted for five or six hours : four kinds of it are made.

Common zaffre has a specific gravity of 35,090 : water being supposed at 10,000.

The use of zaffre seems confined to colour-

ing in blue glass and the enamels, as well as the coverings of fine porcelain ; for this purpose it is melted with the constituent principles of these substances.

There is also prepared for sale, a glass, stained blue by cobalt. It is in Bohemia and Saxony that almost all the azure used in the arts is made : the process is nearly uniform in both places ; the blue of Saxony however is superior to that of Bohemia.

After having roasted, pounded, sifted, and separated the various qualities of cobalt, the oxyde is melted with calcined quartz, and potash calcined also : for this purpose, very white quartz is chosen ; it is pounded, washed, and strongly calcined ; two hundred weight and a half of calcined cobalt are mixed with two hundred weight and eighty-one pounds of calcined potash, six hundred weight of calcined flints, and about forty pounds of white arsenic : this mixture is melted in large crucibles, and it is stirred from time to time ; after a strong heat for eight or ten hours, the glass is taken out with large spoons, and poured into a box, into which fresh quantities of water are continually poured. The crucibles are again

filled, and the operation continues without interruption, until the crucibles or the furnace require repairs, which oblige the workmen to desist.

The glass of azure is then roughly pounded dry, and passed through an iron sieve: it is afterwards brayed under water, by means of mills inclosed in wooden troughs: after six hours braying, the matter is let out by an aperture made in the bottom of the trough: it is carried to a tub, where it is diluted in clear water; it is allowed to settle, and in a few moments it is poured out of this tub, the water being charged with azure in the minutest state of division. The deposit is brought once more to the mill, where it is brayed a second time.

By repeating this manoeuvre, it is easy to imagine that we may succeed in reducing all the azure into an impalpable powder; and that when we bring it all to that degree of impalpability that it remains some time suspended in the water, we may still employ an ingenious process for forming the different degrees of azure known in commerce by the names of first, second, and third sorts, on account of

their beauty. The whole is diluted in a tub, pierced with three holes in its side, perpendicularly, and at equal distances from each other; after a few minutes, the portion of the liquor above the first hole is drawn off, and which contains the finest azure; and the other two apertures are successively opened, in order to draw off all the azure kept suspended.

It must not be lost sight of, that the azure is so much the heavier the more cobalt it contains, which does not always proceed from the proportions employed in the mixture, since an ill-conducted flux, or ill-mixed materials, may produce these inequalities. Thus the most beautiful azure may be precipitated sooner than an azure of inferior quality, although both are brought to the same degree of impalpability.

Glass of azure of a medium quality, has a specific gravity of 24,405, that of water being supposed at 10,000.

Glass of azure, wrought like flint glass, forms the blue vessels which adorn our tables and apartments.

Azure colours the starch employed to give stiffness to silk, linen, and cotton-stuffs. The azury appearance which the colouring princi-

ple leaves upon muslin, calicoes, and linens, renders their white less dull, and more agreeable to the eye, while at the same time the starch gives a body to the stuff.

Azure is used by painters in fresco works.

The annual consumption of smalt, azure, or saffre, in France, is estimated at 4000 hundred weight.

It has been long desirable, that the fine blue of azure could be applied to painting; but its vitreous state, which renders it but little susceptible of combination with oil or size, does not admit of its being applied to this use, and we have been hitherto under the necessity of employing ultra marine exclusively, the high price of which admits of its being used in a very small quantity only.

M. Thenard, to whom I committed, during my administration, the care of some researches upon colours, conjointly with M. Merimée, has found a composition of cobalt, which supplies the place of ultra-marine to advantage; and although this composition is furnished by salts of cobalt, we think it right to publish it in the present article.

Three parts of alumine precipitated from alum

by ammonia, mixed with a portion of arseniate or phosphate of cobalt, both in a jelly, dried and calcined in a crucible for half an hour, form a composition of a fine blue, equal to ultramarine, and capable, like it, of being employed with oil. Experience has justified this assertion; and this blue of cobalt has already become a branch of commerce.

As it is important to know all the circumstances of the operation, in order to be able to imitate it, M. Thenard has given us the method of preparing the arseniate and the phosphate.

In order to obtain the arseniate, the ore of cobalt of Tunaberg, composed of arsenic, sulphur, iron, and cobalt, is employed. It is dissolved in the nitric acid; the excess of nitric acid is driven off by heat; it is diluted in water, pouring potash gradually into it, and a white precipitate of arseniate of iron is at first formed. The latter being totally separated, more potash is added, and a beautiful rose-coloured precipitate is obtained, which is arseniate of potash.

The phosphate is formed by strongly roasting the ore of cobalt, treating the oxyde by the nitric acid, which dissolves it in part, and se-

parates from it the iron in the state of a red oxyde ; we then evaporate to a syrupy consistence, in order to drive off the excess of nitric acid ; it is diluted in water, and a solution of phosphate of soda is poured into it ; a violet blue precipitate is formed, which, on drying, becomes red : this is the phosphate of cobalt.

We may also obtain the phosphate of cobalt by precipitating the solution of nitrate of cobalt by a hydro-sulphuret ; the precipitate is re-dissolved in the nitric acid, crystallized, and decomposed by the phosphate of soda. The blue obtained by this phosphate is more beautiful.

SECTION III.

Of the oxydes of bismuth—(magistery of bismuth, white paint, pearl white).

Bismuth, calcined in a capsule, is converted into a grey and granulated powder, which weighs one-tenth more than the metal employed ; but when this metal undergoes a violent shock of fire, a small blue flame is pro-

duced, and a yellow smoke exhaled, thick and very abundant. Geoffry, jun. observed, that the first vapours formed very white flowers, while the latter were yellowish (*Memoirs of the French Academy*, 1753). It is the same with the oxyde of bismuth as with that of zinc, it does not volatilize, except at a strong degree of heat.

The oxyde of bismuth is very permanent in the fire; it is vitrified into a yellow and transparent glass, which pierces and vitrifies the crucibles. Darcet kept bismuth in a porcelain capsule, and in a porcelain fire: the glass formed in the interior was transparent, of a dirty violet colour, or that of wine lees; the glass which had melted at the extremity was yellow, and resembled the glass of lead.

Of all the known acids, the nitric attacks bismuth with most vehemence; it is decomposed with a singular rapidity over this metal.

We may precipitate the oxyde of bismuth from this solution by means of water; and when we wish to obtain the precipitate very white, we proceed as follows: the dissolution is diluted in equal parts of pure water, and the

deposit formed is thrown away : a great quantity of water is then thrown into the solution ; a fine white precipitate is formed : the liquor is decanted ; the precipitate is washed and dried ; and it is then called magistery of bismuth, white paint, pearl white, &c. One-ninth more than the metal employed is extracted.

This white paint enters into the composition of the pommades employed in France in painting the human face, &c. The oxyde of bismuth has a slight bluish colour, resembling that of a white and delicate skin ; but besides the very great danger attending this kind of painting, by closing up the pores of the skin and suppressing transpiration, it is also attended with the inconvenience of becoming black, from the impression of strong or sulphureous exhalations.

This oxyde also forms the base of the preparation used for blackening the hair. The effect of it may be hastened by the exhalation of sulphuretted hydrogen gas.

SECTION IV.

Of the oxydes of zinc—(tutty, white of zinc).

When, by the labours of metallurgy, zinc has been brought to the metallic state, it may be oxydated at the degree of heat proper for holding it in fusion; it is covered with a coating of grey oxyde; and if care is taken to remove this oxyde as it is formed, the metal is oxydated to its last atom. The oxyde weighs one-sixteenth more than the metal employed.

If we raise the temperature, and make the metal red-hot, the zinc takes fire; it burns with a greenish blue flame, and there flies off a considerable quantity of oxyde in white, silky, or woolly flakes, which is called *tutty*, *ompholix*, *nihil album*, *lana philosophica*.

If, at the moment of the flame breaking out, we cover the crucible, and keep it covered until the flame is extinguished, the capacity of the vessel is filled with the silky oxyde.

But if we remove it as fast as it is formed by the combustion of the zinc, we may reduce a

given quantity of this metal into white oxyde, containing 0,18 of oxygen.

We may give a yellow colour to this oxyde, by keeping it a long time in the melting-fire; it then loses its oxygen, according to the experiments of Messrs. Desormes and Clement.

This oxyde contains more oxygen than the grey does: I obtained from it one-twelfth more than the weight of metal employed; it is also more difficult to reduce it. We may convert it into yellow glass, by a violent fire.

The acids have a very remarkable, and a very energetic action upon zinc: the nitric acid in particular, is rapidly decomposed over this metal; the sulphuric and muriatic acids, diluted in water, dissolve it extremely well, and form salts used in the arts, of which we shall speak in a subsequent part.

The sublimed oxyde of zinc is used in medicine as a remedy. It is used, externally, under the title of desiccatives, in incipient ophthalmias, and it is mixed with hog's-lard. It is also administered internally, in doses of a few grains.

M. Guyton Morveau proposed, some years ago, to substitute the white oxyde of tin for the white leads or ceruses: this oxyde is not

dangerous in its application ; it does not become yellow with the oils ; but these advantages are compensated by some defects, which have hitherto caused it to be rejected : it is lighter than the oxyde of lead ; it does not cover so equally, nor swell sufficiently when used as a pigment. This last inconvenience must very much limit its application : for an artist, accustomed to cover a large surface with a brush charged with white lead, will find some difficulty in charging his brush every moment, particularly when working in common house-painting.

This oxyde is also higher-priced than that of lead, and this difference in price will always give the latter the preference with the artist, although at the expence of his health ; for sad experience teaches us every day, that the workman never thinks of guarding against dangers which do not attack him at the moment.

SECTION V.

Of the oxydes of antimony—(glass of antimony, flowers of antimony, diaphoretic antimony, &c.)

The sulphuret of antimony (crude antimony) enters into fusion at a moderate heat, and its flux is as fluid as water.

But if in place of carrying the heat to the degree necessary for producing fusion, a degree is only given capable of burning the sulphur, in this case the black colour of the sulphuret gradually disappears, and it is replaced by a grey colour, which has caused this oxyde to be called *grey oxyde of antimony, grey calx of antimony*. Whatever care is taken in shaking or stirring the sulphuret we are calcining, it is difficult to prevent it from becoming clotty, which compels us to bray the oxyde as soon as the operation is finished.

The antimony in this state of oxydation, always retain a little sulphur, and it is at the moment when the proportions are such, that

by carrying this oxydated sulphuret to fusion, a glass is produced of a hyacinth colour, which has been called *glass of antimony*.

When the oxyde is less freed upon sulphur, the glass is opaque and brown; its fracture also is not so vitreous, and it has much less hardness: when the oxyde is, on the contrary, too much freed from sulphur, besides being harder to melt, the colour of the glass is much less intense.

Thus, in order to obtain a hyacinth glass, such as is required in commerce, and that its effects may be constant, a just medium must be hit upon between the state of sulphuret and that of pure oxyde.

M. Thenard has given us a very interesting memoir upon the oxydation of antimony: he has recognized five degrees, very well characterized, and containing from 0,02 of oxygen to 0,32. This metal passes successively through the black, brown, orange, yellow, and white.

The first degree is obtained by precipitating it from its solutions, by means of iron and zinc; the oxyde is black, and contains 0,02 of oxygen. It inflames upon simple dessication, in a gentle heat.

The second degree is chesnut brown : it is in this state that it exists in glass of antimony, and in recent kermes. It contains 0,16 of oxygen.

The third degree is orange : it is this preparation which is called gilded sulphur, and it is made by pouring an acid into the liquor, from which the kermes is precipitated. This oxyde, upon analysis, presented only two hundredth parts more oxygen than the second.

If, by means of heat, we take off oxygen from the white oxydes, we may stop the oxydation at all the degrees we have mentioned, and even at a higher degree ; the oxyde, in this last state, is of a yellow colour, and contains 0,19 of oxygen.

It seems that the last degree of oxydation is the white : this oxyde is prepared by several processes :

1st, When antimony is melted, a white smoke is raised, which we may collect by placing immediately above the melted mass, a crucible, or any other vessel in which this oxyde may be condensed : small, minute, very white needles are formed, the geometrical figure of which is that of an elongated octa-

hedron; according to Pelletier. This oxyde is called, *silvery flowers of antimony, sublimed white oxyde of antimony, &c.* It is soluble in water, is sublimed upon burning charcoal, and resembles in several other respects, *the white oxyde of arsenic.*

2d, When we distil two parts of oxygenated muriate of mercury (corrosive sublimate) with one part of antimony, a matter flows into the receiver, of a butyraceous consistency, which has been called butter of antimony, and from which we precipitate a very white oxyde by diluting it with water. This oxyde is known by the name of Algarotti powder; it always retains a portion of acid, which it brings down with it.

3d, The sulphuric and muriatic acids do not oxydate antimony, except by long digestion; but the nitric acid is rapidly decomposed over this semi-metal, and there is produced a considerable quantity of a white oxyde, known by the name of *Bezoard mineral.*

4th, Other preparations in use, are also formed by oxydating the antimony by the decomposition of the nitrates: it is sufficient to project into a red-hot crucible, a mixture of

equal parts of nitrate of potash and antimony. A rapid combustion takes place, the result of which is, a white oxyde mixed with potash, and which is called *diaphoretic antimony*. It bears the name of *washed diaphoretic antimony*, when the potash is separated by washing it in pure water. The oxyde precipitated by the acids from the alkaline solution of diaphoretic antimony, is called *ceruse of antimony*.

The two first of the white oxydes we have mentioned, contain 0,20 of oxygen; the two latter contain 0,32.

The very extensive use of antimonial preparations in medicine, renders all these facts very valuable.

All these oxydes are employed by themselves as remedies, and they also form the bases of various medical compounds of a very active nature; we cannot therefore be too careful in their preparation, which must be guided by science only.

SECTION VI.

Of the oxydes of manganese—(glass-maker's soap, brown oxyde and white oxyde).

Manganese is almost constantly in the state of oxyde; and when by easy methods we succeed in stripping it of a part of its oxygen, or bring it to the metallic state, it easily seizes on the oxygen which may be furnished to it by the air or water, and resumes its natural state of an oxyde.

In the state of oxydation in which manganese naturally presents itself, it is black, and adheres to the fingers.

It is sometimes found in small buttons, like slight bubbles; it is often in crystals, and it forms prisms brilliant in colour, thin, acicular, and often interwoven with each other. The ores of iron, particularly those of the nature of hematites, are often covered in their cavities with a down of manganese. I found oxyde of manganese mixed with oxyde of iron; in the granite of Cevennes, near Saint Jean-de

Gardonenque, in the department of Gard; this metallic mixture exists in the granite in small threads.

When we make the oxyde of manganese red-hot, it loses part of its oxygen, and becomes white. The acids which we cause to act upon this black oxyde, liberate a portion of oxygen from it, and dissolve it; if we precipitate it from them by the alkalis, it resumes the oxygen it had lost with so much facility, that we may make it one of the eudiometrical methods.

For a long time, manganese has been used in glass-works, to clarify the glass, whence it is known by the name of glass-maker's soap. The effect of this oxyde could not be explained, until the moment it was known that the oxygen disengaged from it by heat had a marked affinity for the colouring principles. The violet hue which glass assumes in some cases, proceeds either from employing too much oxyde, or from its not having been carefully enough mixed in the *composition*.

When we put this oxyde into the crucible, at the moment the matter is melting, there are almost always produced, some violet-coloured

streaks; which proceed from the oxyde not having been equally divided among the whole mass. It is this property of manganese, of staining glass of a violet-colour, when employed in strong proportions, that has caused it to be employed as a colouring principle in glass-works, potteries, and porcelain works.

We have already spoken of the properties acquired by the muriatic acid when we distil it over oxyde of manganese: they are certainly owing to the portion of oxygen which it takes from this oxyde.

The brown oxyde mixes very well with the drying oils, and forms a solid colour, which may enrich the art of painting.

SECTION VII.

Of the oxydes of lead—(grey oxyde; massicot, minium litharge).

Lead, of all the metals known, furnishes the greatest number of oxydes for the arts. The variety and vivacity of their colours, their fusible virtues, and the properties they give glass,

have so much multiplied their application, that the preparation of them forms several distinct arts. *Massicot*, *minium*, and *litharge*, are all so many oxydes of the same metal, the manufacture of which is conducted on a large scale for the use of painters, glass-makers, potters, &c. &c.

The most of these oxydes are prepared by the calcination of the melted metal; and although very different in colour, they all proceed from the oxydation of the metal at different degrees of temperature. The rest are owing to the action of the acids upon the metal, and they have a colour and characters peculiar to themselves, which we shall describe.

As soon as the metal is melted, if we keep the heat at the same degree for some time, a coat of grey oxyde is seen, which may be skimmed to the edges of the vessel, in order to facilitate the contact of the air with the metal, and continue the oxydation. In this operation we may obtain an increase in weight of about 10 *per cent.* This oxyde is called *grey calx*, *grey oxyde*, *ashes of lead*.

This first oxyde made red-hot gradually, as-

sumes a yellow colour, which begins by being dirty, and finishes by becoming very brilliant; this new oxyde is known by the name of *massicot*. When we wish to prepare this oxyde for the arts, we begin by oxydating the lead *grey*; this first oxyde is carefully brayed, and exposed in a reverberating furnace, at a heat which keeps it red without melting it. Care must be taken to stir and agitate from time to time the coating of oxyde, and we must stop the operation as soon as we perceive that the small quantity of oxyde which adheres to the spatula we use in stirring the oxyde, assumes, upon cooling, a fine yellow colour.

The manufacture of minium requires more complicated precautions and manipulations. The English and Dutch have hitherto made a mystery of this manufacture; but chemical science has unveiled all the secrets, and we possess several manufactories in France, where minium is successively made. M. Jars was the first to give us some details upon the red-lead works he visited in the county of Derby.

The furnace used for calcining the lead is a reverberatory one, with two fires under the same arch; these fires, which are upon the

sides, at the bottom of the arch, are 15 inches broad by 8 or 9 feet long. The distance of the one fire from the other is 9 or 10 feet : these fires are only separated and divided by a little wall 10 inches high, and which hinders the combustibles from mixing with the oxyde in the middle of the furnace. The combustibles are placed against these little walls. In England coal alone is employed. The English workmen are of opinion, that wood cannot be employed to so much advantage as clear coal. By supposing this opinion to be founded upon experience; and upon the comparative effects of the two combustibles, we cannot reasonably assign it to any other cause than to the volatilization of a portion of the carbon of the wood, which might render the oxydation irregular and incomplete. In France, however, wood is employed with success; and without doubt the superiority of the English minium may be ascribed to other causes.

The air which escapes from the furnace is received into a long flue, which transmits all the emanations to a distance.

They employ at each operation, 10 pigs of lead, each of which weighs 150 pounds; nine

of these pigs are of new, very pure, and very soft lead, melted in the reverberating furnace; the tenth is produced by the melting of the scorizæ, by means of purified charcoal, called *coke*.

It is generally thought that the mixture of this last is necessary for making good red-lead.

As soon as the lead is melted, it is continually stirred, and in proportion as it is oxydated, the workman throws up the oxyde upon the sides.

In four or five hours all the lead is oxydated. The heat necessary for this operation is that of a deep cherry-red.

The oxyde is left in the furnace 24 hours longer, but it is stirred from time to time, to hinder it from becoming clotted.

When the oxyde is perfect, it is thrown down upon a compact pavement, and water thrown upon it to cool it. The workmen say that this gives it weight. This oxyde, when cooling, is of the colour of yellow ochre.

It is carefully brayed in water; the minutest particles are shaken in a cask filled with water, and the sediment formed, is separated from that

part which remains suspended. The sediment undergoes a new calcination, while the fine matter receives a final operation to convert it into minium.

They carry into the area of the furnace all the minutely divided matter ; a heap is formed with it, and a radii or streaks are drawn upon the surface of it. It is carefully stirred ; the fire is kept up from 40 to 48 hours, in the same manner and at the same degree as at first. The charcoal is never stirred, and a fresh quantity is introduced when they think the fire has slackened.

The matter is known to be at the proper degree of calcination, when, on drawing it hot from the furnace, it is of a deep ochre-red colour, and when, upon cooling, it assumes a beautiful red.

The minium, on coming out of the furnace, is put into a large wooden vessel, where it is allowed to cool, in order to pass it afterwards through a very fine iron sieve ; but in order to avoid the respiration of what evaporates in this operation, the sieve is placed in a cask, and supported by two iron bars ; the necessary motion is then given to the sieve, by means of

a stick affixed to it, and which comes through the cask.

In the red-lead works I have examined, I have seen the process practised I have now described, under some modifications, which it is important to make known.

I have seen the lead oxydated in an iron cauldron, without this vessel being ever made red-hot; the oxyde, in this case, assumes a greenish yellow colour.

I have seen the oxyde placed in a hair sieve, suspended in a cask; water passed through it carried off the minuter particles, and separated them by this means from all that was too little oxydated.

The furnace in which the oxyde is calcined, in order to bring it to a state of minium, seemed to me to vary only in point of size: it is generally much smaller than that described by M. Jars. The arch is sometimes perforated with three apertures, made longitudinally, and which join into an apartment, the floor of which is covered with water, and from which there arises a single chimney, which carries out into the open air the dangerous emanations of the lead.

I have seen the oxyde calcined twice : after the first calcination, which is kept for four or five hours at a cherry-red, the fire is allowed to subside ; and as soon as it is sensibly diminished, the matter is stirred with an iron rake : the fire is plugged up, and all the joinings of it are luted, and it is left in this state for 24 hours. On the day after, the furnace is opened to hasten the cooling.

After this first calcination, the oxyde is of a pale red : it is brayed under water with great care ; the finer particles are separated by decantation from those which are coarser ; it is dried in plaister troughs, and as soon as it is dry, it is brayed as follows :

Two cylinders, the one of polished iron, and the other of hard wood, are placed upon the same level, and parallel to each other ; they may be removed from, or brought nearer to each other by means of two strong vices : below these two cylinders are placed two others, constructed in the same manner ; and below these two last there are two of hard wood. These three rows of cylinders are surmounted by a hopper, in which the minium is put ; it is made to flow down through all the cylinders,

and is received into a box below. The movement is given to all these cylinders, or to this treble rolling-press, by the same mechanism. The whole apparatus is covered with masonry, or with planks carefully joined. The motion is given outside, by means of a winch, so that there is no loss, and the health of the workmen is not injured by the emanations. It may be conceived, that the distance between the two upper cylinders ought to be greater than that between those of the middle ones, which, in their turn, ought to be farther from each other than the lower ones.

The minium, after being passed through all these cylinders, is of a proper fineness; but brilliancy of colour is still wanting, which cannot be given without carrying it a second time to the reverberating furnace, where it is treated as at first, with this difference only, that the furnace is not opened until it is almost cooled.

If we treat minium a third time in the same manner, the red colour becomes orange.

The lead augments in weight, about 16 per cent, by passing to the state of minium.

Although there are several red-lead works in

France, and three or four at Paris, under our eyes, we cannot flatter ourselves with making so good an article as that we see every day exposed to sale. We have the mortification of seeing our glass-works supplied with a foreign commodity at a great expence: and I have myself observed, that this predilection is owing to the superiority of the foreign article, which constantly makes a clear glass, while our minium makes it yellowish, brown, or milky.

I have studied the causes of this difference, and I am convinced that they are numerous: 1st, for a long time, lead has been employed which belonged to old buildings, and containing more or less tin, in proportion to the solderings: it results from this alloy of lead and tin, that the oxyde of tin being almost infusible, it must give to glass a milky appearance, almost enamelled; 2d, the lead of our mines is generally very brittle, and contains more or less copper. Now this last metal when it is even alloyed in a very small dose, stains glass of a brown colour, while the pure oxyde of lead colours it of a fine topaz yellow, when they are melted in equal parts.

I have attended for a long time, with the greatest interest, the red-lead works of Messrs. Paillard, at Paris; and I have caused them to operate, under my own eyes, with all the various qualities of lead that could be procured: we have verified, by experiments made on these different products in the glass-work belonging to Creuzot, all that I have here advanced. The best of all kinds of lead for making red-lead, is the pig-lead of England.

M. Pecard, jun. the artist at Tours, having consulted me on the best method of overcoming all these difficulties, I advised him to employ litharge made from a very pure lead, and to retrograde the oxydation, in order to convert it into minium. Some days afterwards he sent me specimens of the minium he obtained by this method, and they did not seem to differ from the best English red-lead. M. Pecard succeeded, after inquiries directed by exact experiments, in converting all the kinds of lead known in commerce into good minium: for this purpose, he afterwards brings it to a state of perfect fusion, which he keeps up by a brisk heat; he takes off all that comes to the surface, *i. e.* the tin, copper, and other

foreign bodies; and when his bath forms at the surface a vitreous and very compact stratum, which may be lifted off like a scum, he continues the operation for making the minium.

M. Pecard's may be compared with the best English red-lead; and the government may now safely, without injuring our crystal-glass manufactories, exclude all foreign minium.

If we produce a white heat, a beginning of vitrification is produced upon the oxyde of lead, and there are produced small vitreous scales, of a darker or lighter yellow, which are called litharge, and distinguished in commerce by the names of *gold* and *silver litharge*, from the colour.

The manufactory of red-lead is always carried on in the founderies of lead-mines; because, from all these mines, containing more or less silver, it is separated from them by cupellation, which converts the lead into litharge. This operation has the double merit of rendering the working more advantageous, by the extraction of the silver, and by giving to the lead afterwards obtained by operating upon the litharge, a ductility, and a kind of softness,

which it would not have if it continued alloyed with this first metal.

When we wish to cupellate or separate the silver from the lead, we begin by calcining bones; the ashes of the calcined bones are carefully washed; and when they are dry, they are slightly moistened, to give them consistence: they are sometimes mixed with well lixiviated ashes, and, in several places, nothing else than this last substance is used. A bed of these earths is formed on the floor of the furnace, to the thickness of about six inches. It is beat very hard to prevent it from cracking, and the form of a saucer is given to it, that it may serve as a crucible to the bath of lead. Its diameter is from five to six feet, its form is round, and the edges of it are higher than the middle by four or six inches. This bed is surrounded by a wall eight or ten inches high. The dome of the furnace is moveable, and it is raised at pleasure by means of a crane. The flame that rises from the fire, is thrown into the furnace, which it traverses, in order to reach the chimney which is opposite; and two large pair of bellows, or trunks, incessantly

direct a strong current of air upon the lead in fusion, in order to facilitate its oxydation. The heat is carried to whiteness, and kept at this degree so long as the operation continues.

As fast as a layer of oxyde is formed on the surface of the bath, the head workman skims it, and throws on the ground this oxyde. By degrees, the lead is converted into litharge, while the silver preserves its metallic state, and at last it remains alone in the middle of the cupell.

In all places where they work lead-mines, it is first converted into litharge, in order to procure the silver; and this litharge is afterwards melted through charcoal, in order to reproduce the lead.

When we wish to preserve lead in the state of litharge, for the purposes of commerce, more care must be taken with it than when it is intended to be reduced. In England, where this manufacture seems to have attained the utmost degree of perfection, a combustible is used, which gives a great deal of heat and little smoke; care is taken not to extract the oxyde from off the bath until it has acquired a

fine colour; the litharge is afterwards sifted with care, in order to separate from it the large vitrified pieces, and the impalpable powder.

The oxydes of lead we have mentioned have common uses and particular properties.

The uses common to all of them, are as follow: 1st, They facilitate vitrification, and give to glass a weight, a softness, a mildness, and an appearance which it would not otherwise have.

Green glass, deprived of lead, has a specific gravity of 26,423; white, or crystal glass, which contains lead, 28,922; and what is called *flint-glass*, 33,293.

Glass, deprived of lead, is dry, brittle, and very hard: glass containing lead, is less brittle, more tender, and admits of being wrought upon by the glass-cutter with greater facility.

Glass, when it has no lead in its composition, has sharp and deep cut angles in its fracture; while that which contains lead, has an unctuous-like appearance, and less sharp angles.

Another property of glass into which lead enters, is that of being better melted, and of being free from bubbles, wiry threads, or streaks; and, in short, from flaws of every kind: it

also refracts the rays of light more perfectly ; presenting to them a medium of equal density in all its parts, and thus collecting them upon one and the same point. This is the reason why it is exclusively adopted for optical glasses.

This sort of glass has one inconvenience only, and it seems to me to be inherent to it, and inseparable from the other good qualities that belong to it : being composed of bodies of unequal gravity, such as the alkalis, silex, and lead, and being obliged, in order to render it proper for its various uses, to bring this mixture to a flux as liquid as water, the principles which enter into its composition are placed, upon cooling, in such a manner, according to their specific gravity, that the bottom of the flux is heavier than the rest. Hence it is so difficult to obtain flint-glass constantly, particularly in a large mass.

Some trials which I made upon the composition of flint-glass, presented the following, as uniting the greatest number of good properties :

	lb.	oz.
Quartzose sand ; very white.....	1	8
Very pure saltpetre.....	0	9
English minium.....	0	8

All the oxydes of lead melted separately yield a yellow glass of an agreeable colour, semi-transparent, which corrodes and pierces through the crucibles in which vitrification takes place.

2d, All the oxydes of lead have the property of rendering the oils *siccative*; it is only requisite to digest them by heat over these oxydes. Painters who prepare their own oils, or those who sell them, tie the oxyde of lead into a cloth, which they hang in the oil while it is heating.

In this operation, the oil acquires the property of drying faster, and of making varnish; besides this, it becomes thick, if too much oxyde is mixed with it. The oil takes a part of its oxygen from the lead, and dissolves a portion of the oxyde into a native state: the oxyde, by thickening it, causes it to resemble those pharmaceutical compositions called *plasters*, and the oxygen renders it concrete, in bringing it to a state similar to that of the resins. It is this double property of the oxydes of lead, which has caused them to be preferred to all the other oxydes.

The oils of linseed and of kernels, are almost the only ones which can be rendered siccative.

Independently of these common uses, each of these oxydes has particular ones: minium is employed as a colouring principle in painting, when it is used in coarser works, instead of cinnabar and vermilion: it is also used for colouring sealing-wax, &c.

SECTION VIII.

Of the oxydes of iron—(ethiops martial, martial saffron, colchotar, mild earth of vitriol, &c.)

The precious qualities of iron, which have so much contributed to supply the wants of society, lose much of their value in consequence of the facility with which this metal is oxydated or covered with rust: so great is this facility, that it decomposes the air, water, and the acids, and we cannot secure it from this alteration, unless we cover it with varnish.

We shall first speak of the methods of pre-

serving iron from rust, confining ourselves to a simple description of the best known processes,

1st, Heat the iron to a slight red by a wood fire, rub it afterwards with wax, or soak it in oil.

2d, Heat it in the same manner, and rub it with horn; a black varnish is thus formed.

3d, Wash the metal, when well polished and well rubbed, with a concentrated alkaline ley; place the article under a muffle covered with lighted charcoal, so as to obtain a high temperature and a current of air: the iron assumes a straw colour, passes to the fawn colour, then blue, and afterwards grey.

4th, Clean the iron by the same process, wash it with water, and wipe it carefully.

Take varnish made greasy with oil, the base of which is gum copal, mix with it spirit of turpentine from one-half, to four-fifths, draw a sponge saturated with this varnish over the piece, and allow it to dry.

This varnish may be applied to all the metals. It is certainly much more important to guard the iron against oxydation than to provoke it; nevertheless, as the arts have appro-

prepared the most of these oxydes, of which a very extensive use is made, we shall describe their preparation.

When we precipitate iron from its recent solution in the sulphuric acid, by means of an alkali, a white precipitate is formed, which suddenly becomes green, and soon becomes red. This rapid progress of oxydation, is owing to the absorption of oxygen; we may be convinced of this, by keeping the oxyde under vessels.

It is in this state of a white oxyde, that the iron is found in the copperas of commerce, which is of a deep bottle green; when the acid is in excess, the colour is then of a clear emerald green.

The combination of the acid with the green and red oxydes, yield sulphates which differ essentially from the former; we shall speak of them afterwards.

Iron has the property of decomposing water; it is sufficient for this purpose, to impregnate with that liquid a layer of iron, reduced to the state of filings or shavings. But when we keep the iron under this liquid for some time, it gradually loses its metallic lustre, be-

comes black and pulverulent, and forms a black oxyde, called *martial ethiops*. In this case, it is chiefly to the combination of the oxygen dissolved in water that the oxydation is owing.

We may produce a similar effect by exposing polished iron to the action of heat: for this purpose, we lay upon a plate of iron some clods, formed with bark, and then cover them with lighted charcoal: when the whole is well inflamed, the pieces we wish to blue are laid above them, and they are turned round, that the effect may be equal upon all the parts: as soon as we think the article has assumed the colour we wish, it is withdrawn, cooled, and wiped with a dry towel; the surface soon assumes a blackish blue colour.

When we keep the fire for some time at a red heat, the surface is oxydated, and forms black scales, which we may detach by percussion: these scales are known by the name of iron-filings; they may be broken under the hammer, and may be easily pounded; they may even pass to the state of a red oxyde, by a prolonged calcination; and there is then developed, by the pounding, a lively and solid red colour, used in the arts.

Iron, exposed to a brisk heat, burns with a very bright flame; iron bars brought to a white heat in the fire, and beat upon the anvil, emit from all parts of them very brilliant sparks; and very pure and impalpable iron filings, when driven through the flame of a candle, burn briskly. We may burn an iron wire, rolled spirally, and at the extremity of which we put a burning coal, by plunging it in a flask filled with oxygen gas.

The contact of the air alone, is sufficient for oxydating this metal: but when its action is assisted by humidity, its effect is speedier.

We may also accelerate the oxydation of iron by multiplying the surfaces of the metal. The oxyde of iron prepared by wetting it, and known in medicine by the name of saffron of Mars, is made with filings which are exposed to the action of the air during the damp season of March: it is stirred and shaken, in order to multiply its surfaces; and the oxyde is separated from it by means of a sieve, in proportion as it is formed. This oxyde is of a yellowish brown colour.

All the acids have the property of oxydating iron; some by themselves, by means of the

decomposition they undergo; the others by the decomposition of the water which dilutes them.

The first impression of certain acids, such as the nitric, when it is very much weakened, produces upon iron a commencement of oxydation which makes the metal of a black colour.

The sulphate of iron is decomposed for preparing the *mild earth of vitriol*, used in polishing hard bodies; by the first shock of the fire, the sulphate loses its consistence; it is liquefied, and there remains a white mass, which becomes red on a brisker heat, and forms *colchotar*. By increasing the fire, the acid is almost entirely dissipated, and we may separate from the residue all the salt that remains, by proper washings and filtrations. The residue forms the *mild earth of vitriol*, which to an extreme state of minuteness adds a considerable hardness: this renders it peculiarly valuable when we wish to polish hard bodies. It is employed along with oil, for making the polish still softer and more perfect.

The nitric acid is decomposed over iron with such an activity, that it lets go the oxyde

already formed in order to oxydate it once more ; a precipitate of oxyde is the consequence of a reddish yellow, and so impalpable that it forms a soft paste, which may be cut, kneaded, and stretched into thin rolls without feeling any grain in it. Stahl knew, and described precisely all the phenomena which attend the action of the nitric acid upon iron ; but he only saw the decomposition of iron in an operation which demonstrates, in a manner equally evident, that of nitric acid.

The colouring principles which bodies present to us, are mostly owing to the different degrees of the oxydation of iron.

The ochres, and the red-browns, so abundant in our globe, owe their colour to very minute oxydes of this metal. We may even vary their shades very much by means of heat : it is thus that the yellow ochres become red ; and it is by calcining the yellow and pure bolar earths, that we form the dark colours used for painting the doors and windows of cottages, casks, and other articles which we wish to protect from the action of the air and rain ; they are mixed for this purpose with the drying oils.

SECTION IX.

Of the oxydes of copper—(copper-filings, blue ashes, verdegriſe).

The colour of copper is altered in the air; but the oxydation of it is always very incomplete. It is only by the action of the acids, or by a brisk heat, that this metal is oxydated.

The oxydes of copper do not present so many varieties as those of some other metals, such as iron, lead, &c. M. Proust, whose name is so celebrated in chemistry, admits of one coppery oxyde alone, containing 0,20 of oxygen.

We shall chiefly confine ourselves to the oxydation of copper by fire, and by the acids.

1st, When we expose a plate of copper to a fire capable of making it red, and keep it some time at this degree of heat, a violet colour is seen to be developed; this is followed by a very bright blue, which disappears in its turn, and is replaced by a dirty colour: in this

last state, the consistence of the metal is altered, its ductility is gone, and we may detach the friable scales from its surface.

Every one knows, that copper exposed to the fire in the midst of coals, colours the flame of a very pleasant greenish blue, which is sufficient to prove that a slight portion of the metal is volatilized. In the workshops where copper is habitually melted, these metallic exhalations adhere to the flues, and form a heavy crust in them, of a greenish grey colour : this is known in all founderies.

On pushing the oxyde of copper to a strong heat, we may convert it into glass of a brown red colour.

2d, Although copper resists the action of the acids, which only dissolve the metals by their own decomposition, or by that of the water which is present in them in the state of oxyde, yet several coppery salts are prepared for the arts, among which is the sulphate of copper ; we may even place it in the first rank, on account of its uses.

The *blue ashes* and *verdegrise*, form the two most important preparations of this oxyde.

We shall only speak of the former at present, because the second is a carbonate which we shall mention when we speak of the saline combinations.

Pelletier has left us some precious researches upon the manufacture of blue ashes; a manufacture unknown in France, even to the present day.

He proposes to dissolve the copper in the cold, in weak nitric acid, and to add well-pounded lime to the solution; by shaking the mixture, and observing that there is an excess of nitrate, a precipitate of a delicate green is formed. The liquor is decanted; the precipitate is washed several times, and we then mix with it, when still moist, a little quick-lime, in the proportion of seven or eight in the 100 of precipitate; the mixture assumes a fine blue colour, and when it is dried, blue ashes are obtained.

The mixture of the nitrates of lime and of copper, precipitated by pure potash, gives blue oxydes, which change into green upon desiccation.

This process of Pelletier always furnished

me with an oxyde of an inferior quality to the fine blue ashes of commerce.

I resumed this labour, and I think the results I obtained are interesting enough to deserve a place here.

If, on a solution of sulphate of copper made in the cold, we pour lime-water, the mixture of the two liquors becomes turbid, and a sediment is formed of a greenish oxyde.

If, in place of pouring lime-water, we pour milk of lime, or lime-water charged with a little lime in very minute division, suspended in that liquid, a precipitate of a greenish blue is formed, which may be separated by the filter.

If we decompose the bluish liquor which passes through the filter, by means of caustic potash, adding it in excess, the precipitate obtained is blue, and preserves its colour; the liquor which then passes through the filter is limpid, like water.

If, in place of precipitating by means of lime-water, we precipitate a portion of the copper held in solution, by means of the carbonate of potash, the precipitate is of a greenish blue, and becomes green upon drying. We may even employ it in this state in the arts:

but, in order to obtain it, the sulphate must not be completely decomposed. On pouring carbonate of potash, or pure potash in solution, upon the liquid which passes through the filter, and which still contains plenty of sulphate of copper, we obtain a blue precipitate, so much the more intense the more the alkali predominates.

In general, the carbonate of potash should be preferred for the preparation of the greens, and the caustic potash for that of the blues. But whether we use the carbonate, or the pure potash, the constant effect that results is, that the first precipitate is greenish, while it becomes blue when the decomposition is complete, and when the decomposing body predominates.

The products obtained by the carbonate are slotty, and often of an unequal colour.

In general, in order to obtain green or blue at pleasure, we begin by pouring very dilute milk of lime in the solution of sulphate; a precipitate is formed, which is filtered: this precipitate is at first more or less green, but it becomes completely so upon drying.

We pour upon the bluish filtered liquor, a

little milk of lime, and pure potash in excess; the precipitate is of a fine blue: it is filtered; the liquor should be as clear as water, which shews that the decomposition is complete.

These precipitates only require to be washed and dried; they must be dried in a dark place, and as speedily as possible, that the air may alter the oxydes as little as possible.

It follows from all this, that in order to obtain a blue precipitate which is not altered in the air, we must carefully take off all the acid that is joined to the oxyde. According to this idea, I evaporated to dryness the nitrate of copper; I dissolved the residue in water, and afterwards precipitated by an excess of lime-water. The oxyde preserves its blue colour, provided the desiccation takes place speedily enough, and under pieces of paper.

A part of the nitrate is decomposed by the evaporation to dryness, so that all the precipitate is not dissolved in the water.

Water of barytes gives a still finer and deeper blue than lime-water.

Ammonia, poured in a small quantity upon a solution of sulphate, occasions a precipitate

of a greenish white ; when we add it in excess, it colours the liquor and forms a blue precipitate, by the solution it effects, of a portion of the oxyde ; but it is sufficient to pass water over the blue precipitate, in order to take off all the new salt that is formed ; we leave untouched a portion of white precipitate, if the dose of ammonia has not been sufficient for dissolving the whole.

The muriate of ammonia, dissolved in the solution of the sulphate, decomposes the sulphate in part, and the liquor assumes a fine blue colour, by the solution made by the ammonia of a portion of the oxyde.

Analysis proved to me, that in all the latter cases there was formed a triple salt, composed of oxyde, ammonia, and acid.

These blue and green colours are of great use in the arts ; they are employed with water and with oil ; and they are also used for staining paper-hangings.

In Hungary, they prepare a considerable quantity of a green powder, which is distributed for sale. The mines of Herren-Grund, two leagues from Neussol, furnish it. The

waters which filter through the old shafts of the mine is charged with this oxyde, which they collect in boxes, into which the water flows. These waters do not hold it in solution, for the ammonia does not change its colour.

In the same mine, and at the depth of 60 or 80 fathom, there flows a water holding sulphate of copper in solution; it is concentrated in copper cauldrons, and afterwards passed into a reservoir, in which it is mixed with a solution of potash; a green oxyde is precipitated, which is dropped upon pieces of cloth; it is washed in large boxes and dried.

What is called in the arts, *Brunswick green*, is made by moistening copper filings with a solution of sal ammonia in close vessels; the precipitate is washed and dried. This preparation is employed with oil, and also for staining paper.

SECTION X.

Of the oxydes of tin—(tin putty).

Tin is the most fusible of the metals, next to mercury. Although its metallic lustre is altered in the air, and although its colour tarnishes, it is not sensibly oxydated at the temperature of the atmosphere; but as soon as it is in fusion, it absorbs oxygen with such facility, that at the moment, its surface is covered with a pellicle of oxyde, which may be easily skimmed off to the sides. The metal is scarcely uncovered, when a new coat of oxyde appears, and in this manner the whole metal melted may be soon converted into oxyde.

It is this first greyish oxyde which the melters of tin, who travel the country for the purpose of re-melting old tin utensils, denominate *dross*: they pretend that they purify the metal by taking off this pretended dross, formed at the surface of the melted mass: they melt it afterwards for their own use, through burning coals, and they only leave their credu-

lous customer a very small portion of the tin he has entrusted to them.

This oxyde, when pounded and calcined for six or eight hours under a muffle, becomes almost white, and very hard: it is then called *tin putty*. Care is taken to stir and shake this oxyde with an iron spatula, during the whole time of the calcination, in order that the oxydation may be equal over all the points.

Tin putty, on account of its whiteness and infusibility, enters into the composition of enamel. This oxyde, without being melted, remains interposed in the midst of the rest of the composition, which is vitrified, and it renders the glass white and opaque, the distinguishing characteristic of enamel.

Tin putty is also employed on account of its hardness, for polishing crystal, spectacle-glasses, steel, and other hard bodies.

Tin, exposed to a very violent and constant degree of fire, presents the following phenomena: a part of the oxyde sublimes in brilliant needles of a very fine white colour; this oxyde covers, if we may use the expression, another reddish and very hard oxyde, under which we find a layer of transparent

glass, of a ruby or garnet colour. The celebrated Becher has already announced, that tin may be converted into glass, without piercing or corroding the crucible.

We may also succeed in forming tin putty, by decomposing the nitric acid over this metal. This process is very expeditious: the oxyde is precipitated in proportion as the acid is decomposed; and although it is of a duller white than the beautiful putty prepared by calcination in the fire, it may be used in many cases.

SECTION XI.

Of the oxydes of mercury—(ethiops per se, red precipitate).

Mercury, the only one of the metals which is naturally fluid, is oxydated with great difficulty. It is indeed possible to change its colour to black, by the simple shaking of the metal in a vessel open to the atmospheric air, and it is then called *ethiops per se*; but the oxydation is confined to this first degree, and

we must employ heat, or the decomposition of the acids, in order to obtain a farther degree of oxydation.

It would seem that the most proper degree of heat for producing the oxydation of the mercury, is that of 80 or 85 of Reaumur's thermometer. A red oxyde of mercury has been long prepared by the name of *precipitate per se*, by placing a layer of mercury in a matrass, the bottom of which is flattened, in order to present plenty of surface to the air; its neck being very narrow, and its orifice capillary: this matrass is exposed to a sand-bath, the heat of which is kept up at the same degree, until the operation is ended. It lasts several months: we see the surface at first covered with a grey dust, which soon assumes a red hue, and finishes by becoming a very bright red. In this state it is called *precipitate per se, red oxyde of mercury*. It seems to me to contain only 0,10 of oxygen.

This oxyde is more fixed in the fire than mercury: by exposing it to a violent heat in subliming vessels, it is partly decomposed; the oxygen gas escape, while the mercury is condensed in the receiver, or volatilizes in the

atmosphere ; there is formed at the same time, a sublimate, which adheres to the sides of the vessels, where it appears as if melted, and often crystallized. The colour of this sublimed oxyde is a fine red.

The nitric acid greedily attacks mercury, and can dissolve a weight of it almost equal to its own : this solution, when properly thickened, forms crystals, which when dried in the fire, finish by yielding a red powder similar to the preceding, and called *red precipitate*. This oxyde comes from the decomposition of the nitric acid combined with mercury : one part escapes in nitrous gas, while the part of oxygen remains in combination with the metal.

In order to give this composition the beautiful colour of the oxyde prepared in Holland and England, I begin by dissolving mercury with very pure nitric acid, marking from 34 to 36 degrees ; I evaporate the saturated solution to the proper degree for obtaining the nitrate of mercury in crystals.

I put this nitrate into a tubulated retort, and in the sand-bath ; I continue the distillation until no more nitrous gas passes over. I then pour upon the residue of the retort, in fresh

acid, half in weight of that previously employed; and I distil in the same manner. I repeat this operation three or four times, always diminishing the proportion of the new acid: after this, I bray the residue with care, and again expose it to a heat capable of making it red; this precipitate is generally of a magnificent colour.

M. Payssé, who had it in his power to follow in person the operations of the Dutch, has given us some very valuable information upon this preparation. He assures us, that a very beautiful precipitate may be obtained by the following process: dissolve, at a proper degree of heat, 50 parts of very pure mercury in 70 parts of pure nitric acid, marking from 36 to 38 degrees. Evaporate by distillation in a retort, and take away the receiver as soon as the nitrous gas begins to appear. The instant the nitrous gas has disappeared, raise the heat, and keep it up to that degree that the mass of oxyde becomes of a lively red. Eight hours of fire is generally sufficient for an operation of 4 cwt.

When the red oxyde is prepared by the above process, and when it is of a fine red, it contains 0,18 of oxygen. I have also com-

posed it by my own method, which gives me 0,20 of oxygen, while the oxydes which present no lustre, only yield it in the proportion of 13 or 14 *per cent.* ♦

The alkalis and lime precipitate mercury from all its solutions, in the state of an oxyde. We are indebted to Bayen for some curious facts upon these precipitates: he observed, that almost all of them had the property of fulminating, upon their mixture with sublimed sulphur: such as the precipitate from the solution of the nitrate by the carbonate of ammonia, the precipitate from the same liquor by lime-water, the precipitate from the solution of corrosive sublimate by lime-water, &c. It is sufficient to triturate half a drachm of it with six grains of sublimed sulphur. There remains, after the detonation, a violet powder, which will yield fine cinnabar by sublimation.

We ought to observe, that the decomposition of the nitrates and the muriates of mercury, by means of ammonia, form triple salts, as in the decomposition of the sulphate. M. Fourcroy considers these salts as a solution of ammonia in two acids: viz. the primitive acid,

and the oxyde of mercury : he conceives from this, that these triple salts constantly retain more mercury and ammonia than the acid contained in it seems to saturate. (Memoires de l'Academie de Sciences, année 1792).

We may also precipitate mercury from the solution of the oxy-muriate (corrosive sublimate) by lime-water, in a yellow powder, which is suspended in the liquor in slight flakes : it is this water thus charged with precipitate suspended in it, which is denominated *phagedenic water*. In order to form this precipitate, it is sufficient to throw half a grain of sublimate in powder into a pint of lime-water.

All the mercurial oxydes are employed in medicine ; the precipitate *per se*, or *red oxyde*, is chiefly used for killing vermin in the heads of children : the parts infected with it are sprinkled with it ; or rather, this oxyde is incorporated with hog's-lard, in order to form a kind of pomatum. We ought to observe upon this subject, that the oxyde, when ill prepared, may retain a portion of nitric acid very much concentrated, which irritates, inflames, and corrodes the delicate parts to which

it is applied, to such a degree, that the head of an infant may be swelled and inflamed, so as to produce dangerous consequences.

The phagedenic water is used for washing ill-conditioned ulcers, particularly venereal ones.

SECTION XII.

Of the oxydes of silver—(fulminating silver).

The old chemistry distinguished the metals from their greater or less facility of oxydation. Silver, gold, and platina, are those which present most difficulty of oxydation; they resist the contact of the air, the action of water, fire, &c. But of these three metals, silver resists oxydation most strongly: Juncker converted it into glass, on treating it by reverberation, after the method of Isaacs, the Dutchman: Macquer, on exposing 20 times successively silver to the fire in which porcelain is baked at Sevres, obtained an olive-green glass.

It was also observed, that this metal, when exposed to the focus of the burning-lens, pre-

sented a greenish vitreous crust upon the stand on which it was placed : silver wires, battered by a kind of electrical discharge, burn and are oxydated.

Although these experiments announce directly the possibility of combining silver with oxygen by means of heat, this oxydation is not very exact, unless by the decomposition of the acids, particularly of the nitric.

The oxyde of the nitrates of silver, precipitated by lime-water, forms the most dreadful fulminating powder we know.

M. Berthollet, to whom we owe this discovery, advises us to dissolve pure silver in the nitric acid : to precipitate this solution by lime-water ; then to decant it, and expose the oxyde to the air for three days. When dry, it is sprinkled with ammonia ; it then assumes the form of a black powder ; this powder is decanted and dried in the air, and it is then fulminating silver.

The simple contact of any cold body is sufficient to produce fulmination ; whence it follows, that this product, once obtained, cannot be again touched, but left in the capsule in

which it was made, and prudence requires that we should operate upon small quantities only.

If we boil in a small matrass of thin glass, the ammonia which has been used in this operation, there is formed, upon cooling, a crust bristled with small crystals, covered by the liquor. It is sufficient to touch those small crystals through the liquor, in order to produce an explosion which breaks the matrass.

All the oxydes of silver are revived by heat: they present no brilliant colours, and in this last respect the arts have hitherto made no use of them.

SECTION XIII.

Of the oxydes of gold—(fulminating gold, purple of Cassius).

Gold is almost unalterable in the fire and in the air: it results from the experiments made with the burning lens, that a portion of this metal, when melted, rose in vapours without being altered. Homberg observed this phenomenon at the beginning of last century.

Every one knows, that the true solvent of gold is the nitro-muriatic acid—(aqua-regia).

The alkalis precipitate gold from its solution; and when we employ ammonia, the oxyde is fulminating: this is what is called *fulminating gold*: it is yellow; it is dried in the shade, in order to obtain a more certain preparation.

The experiments of some chemists have proved, that by gently heating fulminating gold in copper pipes, the extremity of which are inserted into the pneumato-chemical apparatus, we obtain alkaline gas, and that the precipitate can no longer fulminate. This observation was made by M. Berthollet.

Bergman observed, that by exposing fulminating gold to a gentle heat, incapable of causing it to fulminate, its fulminating property might be also taken from it.

When we fulminate gold in tubes, the extremities of which are inserted under a bell-glass filled with mercury, we obtain azotic gas, and a little water.

By triturating fulminating gold with unctuous bodies, we deprive it of the property of fulminating.

All these facts incontestibly prove, that fulminating gold is a combination of ammonia and oxyde of gold. When we heat this combination, the oxygen of the oxyde is liberated, and combined with the hydrogen of the alkali; there results a combustion producing water in vapours, and which must consequently determine an explosion.

If we put plates of tin in a solution of gold, they are soon covered with a purple precipitate, which becomes very abundant, and is diluted in the liquor by the least movement. It is an oxyde of tin, mixed with some atoms of precipitate of gold, feebly oxydated, and which gives it this colour. This precipitate is used in the arts, by the name of purple of Cassius. It serves to give porcelain and stone-ware the fine purple colour with which they are decorated.

We may form this precipitate by the alkalis, and get rid of the alloy of tin by this means.

Ether has also the property of taking up gold from its solution in the acid. This new combination presents this metal in a state of very minute division, and very near the metallic state. The liquor is coloured in yellow; it is known in chemistry by the name of *aurum*

potabile. It has been proposed to employ this ether for gilding iron: it has been said, that by soaking the metal in this solution, the coating of gold was fixed upon the iron; but experience has proved, that this method of applying gold does not cover well, even after repeating the immersion four or six times, and subsequent evaporation, in order to dissipate the ether.

SECTION XIV.

Of the oxydes of tungsten—(tungstic acid).

We find the oxyde of tungsten naturally combined with lime or iron; and when we succeed in separating it, this oxyde, like the acids, has the property of forming neutral salts with lime, magnesia, the alkalis, &c.; this induced Scheele to call it *tungstic acid*.

In order to separate the tungstic acid from the calcareous tungstate, better known by the simple appellation of *tungsten*, or *heavy stone of Sweden*, we must take three parts of weak nitric acid, which is digested over one part of pulverized tungsten; this powder becomes yellow. We decant the liquor, and pour upon the yellow powder two parts of ammonia; the

powder becomes white, and we repeat the action of the acid and the alkali successively, until the tungsten is dissolved *. By precipitating the nitric acid employed, by the prussiate of potash, Scheele obtained a little prussian blue: the potash precipitates from it the lime contained in it; and the ammonia, united to the nitric acid, liberates a white oxyde of tungsten, which has been called tungstic acid. We may make use of the muriatic, instead of the nitric acid.

Scheele and Bergman have regarded the white oxyde as the true tungstic acid. The Messrs. Deluyar have asserted, that in this state it was mixed with a little precipitating acid, and a portion of potash. M. Guyton-Morveau has confirmed these last results, and it seems, that the yellow matter obtained by the first impression of the acid, is the true tungsten acid, and that this acid exists completely formed in tungsten, since the muriatic acid can separate it as well as the nitric acid, by seizing upon the lime.

* There is often a little quartz mixed with it, which remains insoluble.

When we calcine this acid for a long time, in contact with the air, the yellow colour becomes darker, and passes to green.

The acid, thus calcined, is not soluble in water, and has no taste.

The same oxyde is combined with iron in the mineral called *wolfram*.

In order to separate the oxyde, or tungstic acid from it, we boil for a quarter of an hour, upon the wolfram in powder, thrice its weight of muriatic acid; there is formed a yellow powder as soon as the liquor begins to heat. Upon cooling, the liquor is decanted, and the deposited matter is lixiviated; ammonia is digested over this last, and at several successive times, until it can dissolve no more; the ammonia is evaporated, the residue of the evaporation is calcined, and we obtain a yellow powder, which is the true tungstic acid.

This acid has not yet been used in the arts. Messrs. Deluyar, who have made some very interesting inquiries upon this oxyde, have tried its combinations with all the known metals; and it results from their numerous experiments, that it is combined with almost all of them, even with gold and platina. We

may presume, that in all these cases, the oxyde has been reduced to the state of metal in the crucibles; which have been used, because otherwise there could have been no alloy.

SECTION XV.

Of the oxydes of molybdenum — (molybdic acid).

Molybdenum is almost always combined with sulphur; and it is this sulphuret which is generally employed when we wish to obtain the acid oxyde of this metal:

We may oxydate the sulphuret by calcination, in one crucible covered by another: a white matter is sublimed, sometimes crystallized, which is the molybdic acid.

We may also decompose the sulphuret by the nitric acid, which attacks it very forcibly, causes a great quantity of nitrous gas to escape, and gives, as a residue, a white powder. We employ 30 parts of nitric acid, which we introduce by employing six parts of it each

time. The white powder heated in a crucible and well washed, is pure molybdic acid.

We see evidently, from these two processes, the most simple of all for obtaining the molybdic acid, that this acid does not exist in that state in the mineral, but that it takes its nature and characters by the ulterior oxydation produced by the calcination, or the decomposition of the nitric acid.

M. Klaproth extracted this acid from a yellow ore of lead.

The molybdic acid is white; it leaves an acid and metallic taste upon the tongue.

Its specific gravity, according to Bergman, is, to that of water, as 3,460 is to 1000,

It is not altered in the air; it is volatilized by the blow-pipe into needle-formed crystals.

It is dissolved in 566 parts of water, at a moderate temperature.

It takes up the barytes from the nitric and muriatic acids.

It decomposes the nitrate of potash, and the muriate of soda, by the dry way.

It displaces the carbonic acid from its solutions.

It dissolves several metals, and assumes a

blue colour in proportion as it gives up its oxygen to them.

SECTION XVI.

Of the oxydes of chrome—(chromic acid).

Chrome is found in the acid state in the red-lead of Siberia, and in the state of oxyde in the emerald, and in green lead.

In order to obtain the chromic acid, we must boil red-lead, reduced into powder, with two parts of carbonate of potash; the alkali combines with the chromic acid, and forms a salt of an orange yellow colour, susceptible of crystallizing without changing its colour. We decompose this new combination by the mineral acids; and by evaporation we obtain, 1st, the salt formed by the acid employed and the alkali; 2d, crystals in elongated prisms, of a ruby colour, or chromic acid.

We may also make use of the muriatic acid, which takes up the lead, and sets free the chromic acid.

The chromic acid is of an orange red colour, and it has a pungent and metallic taste,

It is easily dissolved in water, and its solution, when inspissated, furnishes small crystals in elongated prisms, which have a ruby red colour.

Paper, iron, and tin, soaked in this solution, and exposed to the rays of the sun, assume a green colour.

It transforms the muriatic acid into oxymuriatic acid, by the assistance of heat, and the liquor becomes green.

When melted with phosphoric glass and with borax, it communicates to the glass a fine emerald colour.

It seems to result from all the facts known, 1st, that the chromic acid yields, in almost all its combinations, a beautiful ruby red colour; 2d, that the oxide of chrome gives them a lively emerald colour.

It cannot be doubted that the arts, and particularly painting, and those which have the colouring of glass, enamels, and porcelain, for their objects, will soon adopt a colouring principle from chrome, which can furnish all the shades of the finest green, and the most brilliant and solid reds. M. Brongniart has

already employed with success the oxyde of chrome, for giving a beautiful green colour to porcelain.

The department of Var presents us with this metal in abundance (near Gassin, at the Bastide de la Carrade). It is only requisite to separate from it the oxyde of iron, alumine, and silex, that are combined with it, in order to employ it for every purpose, and to try the best methods of multiplying its uses.

CHAPTER VI.

*Of the combinations of oxygen with hydrogen—
(water).*

WATER is the result, best known, of the combination of hydrogen with oxygen; and as this fluid acts in almost all the operations of the globe, and as, without it, there is neither life nor action, its study interests us in a peculiar manner, particularly when we regard it with respect to its formation and its decomposition.

The effects of water have been successively observed by all men who have studied the operations of nature, but it is only since the discovery of its constituent principles, that we have been able to explain the cause of all the phenomena which belong to its formation and decomposition, and to follow its action in all the facts it presents to our observation.

As the discovery of the principles which constitute water forms one of the most brilliant epochs of chemistry, and as it is to this

we may ascribe, not only the rapid progress of some arts, but the explanation of the principal phenomena of vegetation, of oxydation, of the action of the acids, of the production of the salts, &c. we think it our duty to enter into some details upon every thing that prepared and led the way to this important discovery.

In 1718, Geoffroy extracted 5 ounces 7 drachms and 36 grains of pure water, by the combustion of 8 ounces of alcohol well dephlegmated.

Boerhaave proved and varied this experiment with similar results.

Juncker some time afterwards published, that the flame of alcohol was converted into water.

Stahl, in his Treatise upon the Salts, chap. ii. quotes and describes an experiment of Kunckel, which consists in mixing and distilling a volatile oil, with the concentrated sulphuric acid. *It is a very remarkable phenomenon* (he says) *to observe, that the essential oil employed has been decomposed for the greatest part into water.* He adds: *We find a greater quantity of water than there was in the concentrated sulphuric acid.*

The comparison of the refringent power of water with that of various diaphanous substances, had already led the great Newton to regard water as a medium substance between the inflammable and non-inflammable bodies ; he thinks that it is this fluid which furnishes animals and vegetables with their combustile and inflammable principle.

In 1776, Macquer ascertained, that the combustion of hydrogen gas yielded pure water.

Walter had observed, that when we lighted by the electrical spark, in close and very dry vessels, a mixture of common air and hydrogen gas, the sides were charged with humidity.

Mr. Watt, on the 22d of April, 1783, wrote to Dr. Priestley, in order to inform him, that he thought that water was composed of vital air and of phlogiston, deprived of a portion of latent heat.

Mr. Cavendish was struck with the quantity of water furnished by the combustion of hydrogen gas.

But it was not until the 24th of June, 1783, that a public and rigorous experiment, made by Lavoisier, proved the composition of water,

by the direct combination of oxygen and hydrogen gases.

Nearly at the same time, M. Monge established the same doctrine at Mezieres, by combining and operating the combustion of these two gases by means of the electrical spark.

This discovery, which overturned all the ideas hitherto received, and presented to physics a new light by which to guide them to the causes of phenomena, met with partizans as well as detractors. But the experiments by which this fluid has been composed and decomposed, have become so numerous and precise; the results have so rigorously agreed; observation, and all the phenomena presented by the action of water upon all organic and inorganic bodies, concur so naturally in supporting this doctrine, that at present there are few physical truths equally well established; and we may rank the composition and decomposition of water among the fundamental axioms of science. In order to establish this theory, we shall here confine ourselves to the most authentic experiments. We might trace the action of water throughout all the operations of nature and art, if we wish to multiply

our proofs ; because we may constantly observe the same facts, and the same consequences must be drawn from them.

SECTION I.

Of the decomposition of water.

1st, On passing water through a red-hot iron tube, and receiving the products which escape, in the hydro-pneumatic apparatus, which is carefully adapted to one of the extremities of the tube, we obtain hydrogen gas ; and the interior of the tube is oxydated. The increase in weight of the tube, and the weight of the hydrogen gas, is equal to the weight of the water employed.

The most rigorous and most authentic experiment of this kind with which we are acquainted, was made in presence, and by order, of the Academy of Sciences : they took a gun-barrel, in which they introduced coarse iron wire, flattened under the hammer ; the iron and the gun-barrel were weighed ; the latter was covered with a luting, proper for preserving it from the contact of the air ; it was

afterwards placed in a furnace, inclining it so that the water might filter through it; they placed at its higher extremity a funnel for containing the water, and permitting it to run, drop by drop, by means of a stop-cock: the funnel was closed in order to avoid all evaporation of the water. At the other extremity of the gun-barrel was placed a tubulated receiver, intended to receive such part of the water as might pass through without being decomposed; to the tubulure of the receiver was adapted the pneumato-chemical apparatus.

For the sake of greater precaution, a vacuum was made throughout the whole apparatus before beginning the operation: at last when the gun-barrel was red hot they introduced the water, drop by drop, and a great deal of hydrogen gas was extracted. When the experiment was ended, the gun-barrel had increased in weight; the iron filings which were in its interior were converted in a layer of crystallized black oxyd of iron, like the ore of iron of the island of Elba: this iron was in the same state with that burnt in oxygen gas; and the augmentation in weight the iron had acquired, added to the

weight of hydrogen obtained, form precisely the weight of the water employed.

2. When we dissolve iron or zinc in sulphuric acid, diluted by 6 or 7 parts of distilled water, the metals are oxydated, and plenty of hydrogen gas is extricated. The water remaining is not in the same proportion with that which has been employed; the loss it has undergone is equivalent to the amount of the weight of the hydrogen gas, and to the increase in weight acquired by the metal.

If in place of assisting the decomposition of water over iron by the mixture of the sulphuric acid, we confine ourselves to forming a paste with iron in a very minute state of division and very pure water, the metal is oxydated; hydrogen gas is liberated; the mass dries, and the weight of gas, along with the weight acquired by the iron, amount to the primitive weight of the water.

The same phenomenon is more speedily produced if we introduce a little sulphur into the mixture: in this case the oxygen of the water acts upon the iron and the sulphur.

Messrs. Hassenfratz, Schultz, and Bettancourt have remarked, that the immersion of

red hot iron into water always disengages from it hydrogen gas, which takes fire.

Every person knows that the steam of water increases the intensity of fires ; and that this liquid when thrown upon a greasy or unctuous body very hot, produces an inflammation of it.

I have had occasion to be convinced that the humid air of trunks produced more effect than an equal volume of air pushed from a pair of bellows by the same force. All these phenomena depend upon the decomposition of water, the oxygen of which fixes upon the body in combustion, while the hydrogen is dissipated.

3. If we attentively observe what passes in the operations which belong to the decomposition of vegetable, animal, and mineral substances, we shall see on every occasion, that water is the principal agent of these decompositions : we shall see it in the bowels of the earth and in close vessels, supply the presence of the atmospheric air, and furnish oxygen which is fixed upon the bodies while the hydrogen, set at liberty, is reduced to the state of gas. We shall see it furnish the acidifying principle, almost in every case where acids are

formed, and also prepare by this means the most powerful agents of the operations of nature and art.

4. Independently of the action which water exercises upon dead or inorganic bodies, it exercises a very marked influence upon living beings: it is one of the most powerful elements in the nutrition of vegetables; it is decomposed in their texture, and furnishes the inflammable principle which abounds in plants, while its oxygen is driven off, or becomes a principle in the vegetable, concurring to form their acids, resins, &c.

SECTION II.

Of the Composition of Water.

In February 1785, we operated at the house of Lavoisier, by the help of the gasometer, which he himself has described in his Elements of Chemistry, the combustion of $2,364\frac{66}{100}$ grains of oxygen gas, and of $471\frac{123}{100}$ of hydrogen gas; from which must be deducted, 1st, 456 grains for the weight of the gaseous residua; 2d. 35,25 grains for the humidity of

the hydrogen, so that there remains in total weight 3188,4 grains of gas. We collected 3219 grains of water, that is 31 grains more than the weight of the gases; which arises from some error which has crept into the estimation of the weight; this water was acidulated. It was ascertained by this experiment that 100 parts of water were formed of 85 of oxygen and 15 hydrogen.

Another experiment made on a very large scale, and in presence of almost all the chemists in Paris, is that which was begun by M. Lefevre Gineau on the 23d of May, 1788, and finished on the 7th of June in the college of France: the oxygen gas extracted from the oxyd of manganese, occupied a space of 35085,1 cubic inches at the temperature of 10 degrees above 0 of Reaumur's thermometer, and at the pressure of 28 inches of mercury, it weighed 18298,5 grains.

The hydrogen gas, produced by the mild solution of iron in sulphuric acid, diluted with 5 parts of water, occupied a volume of 77267,4 cubic inches, and weighed 4756,3 grains.

The total of the two gases formed a weight of 23054,8 grains, from which taking the por-

tion not consumed, which was 2831 grains, there remains for the weight of the gases combined 20323,8 grains.

The water produced weighed 20293.

There was a deficit therefore of 30,8 grains or $\frac{1}{17}$ of the total.

The weight of the produce, which in Lavoisier's experiment surpassed that of the substances employed, and the deficiency in the latter, prove to us that these slight differences proceed from errors unavoidable, in experiments so tedious and so delicate. The approximation also of the weight of the gases with that of the water obtained, is a prodigy which cannot fail of being felt by those who turn their attention to enquiries of this description.

The specific gravity of the water produced by M. Lefevre Gineau, compared with that of distilled water, was in the proportion of 1,001025 to 1; while that of Lavoisier's experiment was as 1,0051 is to 1. It was acid, and contained 23,63 grains of nitric acid.

A third experiment was made upon the composition of water by Messrs. Fourcroy, Vauquelin, and Seguin: and although it could

only confirm the doctrine already received upon the constituent principle of water, it deserves to be known with respect to the precision of all the operations, and the rigour of the results. Besides, the gases used in the combustion were extracted from substances different from those which had furnished the first, and the water obtained gave no trace of acidity. In all these respects this experiment may be regarded as new, because by confirming known results, it enlarged and perfected our knowledge.

The hydrogen gas was extracted from the solution of zinc in the sulphuric acid, weakened by six parts of water.

The distillation of the crystals of oxy-muriate of potash, furnished oxygen gas.

The volume of hydrogen gas was 25963,563 cubic inches, at the temperature of $13\frac{1}{2}$ of Reaumur, and at 28 inches of the pressure of mercury in the barometer.

The weight of this gas employed in the composition of water was 1039,358 grains.

The volume of oxygen gas, at 28 inches of pressure, and at a temperature of 14 degrees, was 12570,942 cubic inches.

The weight of gas made use of in the composition of the water is as 6209,869 grains.

The total weight of the fluids employed in the composition of the water was therefore 7249,227 grains, or 12 ounces 4 drachms 49,227 grains.

The weight of water obtained was 7244 grains, or 12 ounces 4 drachms 45 grains.

There is therefore a deficit of 4,227 grains.

The eudiometrical trials had announced that the total volume of vital air only contained 415,256 cubic inches of azotic gas; of this there was found at the end of the experiment 467: which establishes an augmentation of 51,744 cubic inches.

The water obtained was not acid; it possessed all the properties of the purest distilled water. The celebrated conductors of the experiment attribute this difference between the water previously produced by the combustion of the gases and their own experiments, to the combustion having taken place very slowly in their experiment, the heat was never high enough to produce the combination of the azote with the oxygen.

This operation was continued without interruption for 185 hours.

The experiment of M. Lefevre presents us for 100 pounds of water :

Oxygen	$84,8=84\frac{5}{8}$
Hydrogen	$15,2=15\frac{1}{2}$

The experiment of the decomposition of water presents the following results for 100 pounds of water.

Oxygen	$84,2636=84\frac{1}{4}$
Hydrogen	$15,7364=15\frac{3}{4}$

The experiment of Messrs. Fourcroy, Vauquelin, and Seguin, presented in 100 pounds of water.

Oxygen	85,662
Hydrogen	14,338

From this last experiment we may also draw the following consequences:

1. That the weight of hydrogen is to that of oxygen as 14,338 is to 85,662.
2. That one pound of water is composed as follows :

Oxygen	13 oz. 5 dr. 46,67 gr.
Hydrogen	2 2 23,33

3. That the volume of oxygen gas for the composition of hydrogen is to that of hydrogen in the proportion of 1 to 2,052.

4. That in order to obtain one pound of water, we must burn,

Pure oxygen gas	15,837 cubic inches.
Pure hydrogen gas	32,523
Total	48,360 cubic inches.

The decomposition of ammonia by the oxy-muriatic acid, or by certain metallic oxyds, produces a quantity of water, which is owing to the combination of the oxygen of these last with the hydrogen of the alkali. The azote forming its constituent principle, is liberated in the gaseous state.

The detonations of the metallic precipitates by ammonia, only produce the terrible effects with which we are acquainted by the formation and sudden vaporisation of a portion of water.

The fine experiments of Lavoisier and Seguin, have proved that water is formed even by the act of respiration; and that oxygen applied upon any particular spot of the living body produces water or carbonic acid, according as it combines with hydrogen or with carbon.

The phenomena of vegetation also present

to us the production of this phenomena in several cases ; the ripening of the fruits indicates an abundant formation of water.

Combustion also produces it in enormous quantity ; Lavoisier formed 18 ounces of it by the combustion of 16 ounces of alcohol.

I have often remarked that the distillation of vegetables strongly acid, decomposed the acid, and that there resulted much more water than the plant contained in its primitive state.

The decomposition of the acids over most of the animal and vegetable substances produces water.

Fermentations and putrefactions, by altering those bodies which undergo their action, take oxygen gas from the atmosphere, and occasion the formation of a portion of water.

Knowing once the constituent principles of water, it will be easy for us to follow its action in all the phenomena, which belong to its decomposition ; but in order to have an exact idea of this fluid, we must consider it under its different relations. We may therefore consider it in three states through which the changes of temperature can cause it to pass ; the division embraces its manner of existence in every cir-

cumstance, and consequently it is very proper for fixing our ideas as to the part it performs in all the operations of nature and art.

SECTION III.

Of Water in the state of Ice.

If the temperature of our planet was permanent below the degree of zero in Reaumur's thermometer, these enormous masses of fluids, which form seas and lakes, would add new solid masses to our continent; springs, torrents, and rivers would exist no longer; animals and vegetables, whose life is supported by this fluid, would no longer receive through their pores the aliment which is necessary for them. Soon would portions of these transparent masses of crystals detached by the hands of men, driven by the wind or carried off by the new liquids which would be condensed upon the surface of the earth, present to us a mixture more or less confused of all the solid materials which are at the surface of our globe, and the portion of our planet formed by the crystals of ice, would

present to us the same phenomena with the present mountains.

But the cold which is necessary in order to retain water in a constant state of ice, is not the permanent state of the temperature of our atmosphere; and it is only upon some points of our globe that the ice seems to be eternal, while almost every where else, water presents to us the alternate passage from the liquid to the solid or gaseous state, according to the seasons or temperature.

The freezing of water presents us with some phenomena, which seem to be constant enough to deserve being described.

1. Fahrenheit, Treiwald, Beaumé, and De Rattes, observed that water may contract a degree of cold more considerable than that of ice, without freezing: it has not, however, escaped the penetration of these philosophers that a slight shaking given to the vessels which contain the liquid, often produces its congelation; and that the thermometer then rises to the freezing point. But we are indebted to the celebrated Black of Edinburgh for having made known, in 1775, that this phenomena does not take place when we employ water which has

been boiled, which seems to prove that the existence and interposition of bubbles of air in the liquid retards the congelation. It is upon this principle that, in the East Indies, they put water, which has been boiled, into the vessels in which freezing is intended to be produced. —Philosophical Transactions 1775, Memoir of Robert Barker.

This phenomenon has some connection with a well known observation upon the crystallization of certain salts, which cannot produce vigorously sometimes, except by a slight agitation of the liquid strongly concentrated; and we ought to observe, that this peculiarity takes place with those salts alone, which fix themselves or form into a mass, and not with those, the crystals of which are formed in an isolated or separated manner in a liquid, and this establishes a second point of analogy between the crystallization of these first salts and the freezing of water.

2. It is clear from the experiments of the academy *del Cimento*, that hollow and metallic spheres filled with water and exposed to temperatures capable of producing the freezing of the liquid, will burst with a great noise.

Every person knows that the trunks of trees crack as soon as the sap freezes, and that the hardest stones break with a great noise as soon as the water which impregnates them passes to the state of ice. From these facts it has been concluded that frozen water occupies a larger volume than fluid water. But M. Vauquelin observed that several salts, on crystallizing in open vessels, and diminishing also in volume, on passing to the state of crystal, produced the rupture of the vessels, which leads us to conclude that the explosion occasioned by freezing does not necessarily prove the augmentation in volume that has been attempted to be inferred from it.

These results, although well established, are not easy to be conceived; because by admitting even that the fracture of the vessels was produced by an augmentation in volume on the part of the body which is frozen, it would always remain to be explained why the power which determines crystallization could overcome a resistance so powerful as that which is opposed to it by the thick sides of a ball of metal.

3. The preceding phenomena have already

convinced us that ice is the state of water in crystals. But we have observed that here, as in the crystallization of some salts, all the liquid is fixed, and that consequently it is not always possible to distinguish the form which is proper to the crystal; this obliges us to recapitulate the principal observations that have been made upon those principles.

De Mayran remarked that the needles of ice joined constantly at an angle of from 60 to 120 degrees.

Pelletier found in a piece of fistulous ice, crystals in quadrangular prisms, flat and terminated by two dihedral summits.

M. Sage remarks, that if we break a piece of ice containing water in its centre, the latter flows out, and we find the cavity fringed with tetrahedral prisms terminated by four sided pyramids. Frequently these prisms are articulated and crossed through each other.—Sage *Analyse Chim.* tom. I. page 77.

M. Macquart observed, that when the snow fell at Moscow, and when the atmosphere was not too dry, it is found loaded with beautiful crystallizations, flattened regularly, and as thin as a piece of paper. It is a junc-

tion of fibres, which issue from one common centre in order to form six principal rays, which are divided themselves into small and extremely brilliant fascies. He saw several of these flattened rays which were ten lines in diameter.

I have often observed that these hoops of crystals, which are formed upon vegetables and other humid bodies by the effect of a hoar frost, were segments of rombs only, sometimes grouped, but often isolated.

Snow presents us with a crystallization of water more regular than ice itself: we have already observed that ice may be compared to those masses of salt which are formed by the freezing of all the liquid; but the crystallization of snow takes place in a fluid which admits of every crystal isolating itself, and assuming its determinate figure: this crystallization therefore constantly affects the form of a regular hexagon when the snow falls in a calm day. The agitation of the air, the temperature of the surface of the earth, determine infinite modifications in crystals, by breaking them, deforming them by the shock, or by producing the fusion of the angles and points by the mere transition of the icy particles to a

warmer temperature. These snowy crystals swell and join into groups, more or less, passing through the atmosphere, more or less cold, more or less charged with humidity, and traversing in their fall a more or less thick layer of atmosphere.—Vide the Memoir of M. Monge upon the cause of the principal phenomena of Meteorology.

When the air is charged with humidity, if the temperature facilitates the freezing of the liquid suspended in the air, it takes up and precipitates those small crystals almost imperceptible, and scarcely formed; this is called *hoar frost*.

This phenomenon is analogous to that which takes place in a saline solution, the crystallization of which is disturbed by a continual agitation; in this case, the small crystals, separated and formed by cooling, are precipitated to the bottom of the vessel, and present a crystalline powder only, every grain of which presents the form of the crystal very distinctly.

As water is the vehicle or solvent of most of the salts, advantage is taken of the facility with which it freezes, in order to extract or concentrate these saline substances; it is thus that in

the north of Europe they concentrate sea water by freezing it, in order to extract the salt from it ; and in our work-shops we concentrate most of the vegetable acids, by exposing them to a temperature which freezes the water in which they are diluted.

Ice, so long as it exists in this state, exposed to a higher heat than its own, always preserves the same degree of temperature so long as it is in the solid state. We may therefore regard the degree of temperature of melting ice as constant, and it is upon this invariable basis that the gradation of the thermometer has been established. We may also lower the temperature of ice, by mixing it with saline substances, and by facilitating the solution of this mixture in a small quantity of water, by a great deal of shaking. We may procure by this means, temperatures from 11 to 15 degrees of Réaumur, and make use of this artificial cold for freezing liquors, juices, &c.

Ice brayed and melted in very pure concentrated nitric acid, may produce cold from 30 to 32 degrees of Réaumur, capable of freezing mercury.

SECTION IV.

Of Water in the Liquid State.

It is in the liquid form that water presents itself almost every where at the surface of the globe, and it is in this state we use it.

Water, as it is furnished to us by nature, is never pure ; it always contains air and some particles of salts, generally the earthy ones ; but these matters do not limit its uses, provided always that their proportion is not too strong. In general running waters are finer than stagnant ; and among the former, those which flow through primitive earths, are also purer than those which flow through the secondary soils : the soil, in the former case, is insoluble and indecomposable, while in the latter it incessantly effloresces, and there are formed salts which the water that impregnates it dissolves and carries off.

The water which proceeds immediately from the melting of snow is very pure ; but it is not sufficiently aerated, which renders it insipid and heavy as a drink.

The water which falls from the atmosphere in the form of rain is the purest of all: it is not exempt, however, from foreign substances, and it holds more or less salts in solution, as Margraaf has proved. The first rain water that descends is generally not so pure as the last; that which is produced in a storm is always less pure than that in a gentle shower; what is driven by a sea wind contains muriate of soda, sometimes in such abundance that it is perceptible to the taste upon the sea-shore.

When waters contain enough of foreign principles to produce upon the human body medicinal effects, they are then distinguished by the name of *mineral waters*.

As water is the vehicle or solvent the most employed by chemists in their researches, they would be exposed to errors in their results if this fluid was made use of as it is presented to us by nature: it is important to bring it to the proper degree of purity, and this is attained by *distillation*. By this operation the water is reduced into a vapour and condenses in a receiver, is purified of all the saline principles it held in solution, and it is then known by the name of *distilled water*.

We find traces of the distillation of water in the most remote ages: the first navigators in the islands of the Archipelago, filled their kettles with salt water, and received the vapour from it in sponges placed above.

The distillation is so much the speedier and more easy as the pressure of the air is less upon the surface of the liquid: it is known that the fluids condensed by the weight of the atmosphere, are resolved into vapour in the vacuum of the air-pump. To this principle we must refer the observations of almost all naturalists and philosophers, that water is much easier of being boiled in proportion as it is elevated on a mountain; and it is by a natural consequence of these principles that M. Achard, of Berlin, has constructed an instrument for judging of the height of mountains by the facility of the ebullition of liquids. Mongez and Lamanon, two of the unfortunate companions of La Perouse, observed that ether evaporated with prodigious facility upon the Peak of Teneriffe. M. de Saussure made a similar observation upon the mountains of Switzerland; and Messrs. Rochon and Lavoisier, from all these facts have drawn practical consequences for

facilitating distillation, by subtracting in whole or in part the weight of the column of air that rests upon the liquid we evaporate.

Water, in the liquid state, exercises powerful affinities upon almost all bodies, but these affinities are not equal for all : it endeavours to unite some of them, such as sulphuric acid, pot-ash, &c. and it repels the union of several others, such as the fats, the oils, the metals, &c. : in general it has more affinity for the saline substances than for others.

In the various combinations, water presents to us characters which appear to belong to it essentially : when it is in exact proportions, it determines the transparency and the solidity of almost all the salts ; it is sufficient to convince ourselves of this fact to see what passes in crystals deprived of their water of crystallization by fire on the action of the air alone ; they lose at once their transparence and solidity. When by means of heat we have dissipated the water of the transparent crystals of gypsum, and given them a pulverulent consistence, we may re-establish their solidity by restoring to this powder the water of which we have deprived it. We may observe similar effects on

the part of water in the formation of gluten, the manufacture of glues, &c,

When we present this liquid in excess to the various substances which have an affinity for it, it resolves them, and gives them the exterior character which distinguishes it. Its different degrees of affinity with various bodies establish infinite degrees in its resolvent virtue.

This resolvent virtue, which water exerts over all points of the globe, is the principal cause of the displacement of all the substances which are more or less soluble in this liquid. The salts, of whatever nature, are scarcely formed, when water discolours them: evaporation, motion, or stronger affinities, afterwards decide their precipitation. This same fluid, in virtue of the same resolvent faculty, carries every day to the surface of the earth the substances which have been elaborated in its bowels; and it is also this resolvent virtue which furnishes the chemist with the means of extracting and ascertaining the salts, at the same time that he finds, in the property which water possesses of evaporating itself, simple methods of obtaining them under the most regular form.

If we examine attentively the resolvent action of water upon the various bodies, we may observe two very remarkable effects: frequently the solution is complete, and the body in solution disappears to the view; but in several cases water only unites the parts, increases the volume of the mass, and gives it transparency. We see these last phenomena in the manner in which water acts with alumine, magnesia, feculæ, mucus, albumen, &c. Here it is a semi-solution, or the molecules are disjoined and separated into a great degree of tenuity by the interposition of the liquid.

Not only does water act as a solvent upon organic and inorganic products, but it also exercises an action more or less direct upon them, by its own peculiar constituent principles.

This liquid, when moistening metals which are very liable to oxydation, is decomposed over them, the oxyd and its hydrogen escapes in the state of gas. Its decomposition becomes speedier, when it is united to a body which exercises very decided affinities upon the metals, such as the acids.

It is to the decomposition of water in the bowels of the earth that we may refer the

greatest number of changes and revolutions which take place : the sulphurets and phosphorets, so abundant in the bowels of the earth, would undergo no alteration, if the oxygen which changes them, and forms acids with them, was not furnished by the decomposition of water ; thus we see the sulphurets effloresce when they are not saturated by this liquid. In all cases, the oxygen of the water joins the sulphur, and forms sulphuric acid, while the acid becomes free, escapes, often with noise, from the fire which has produced it, and produces earthquakes or volcanic eruptions. On the other hand, the acid produced tends to form combinations with all the materials which were in the furnace of its formation ; whence result sulphates of all kinds. The water then dissolves these new salts, and brings them to the surface of the globe, which is the principal cause of the formation of mineral waters, or rather the convulsive movements determined by the result of these decompositions, and the heat which accompanies them, sublimes them, or forces them out, which is the reason why we have successively found all these products confounded with volcanic products, or sublimed in

the flues or passages which give vent to these subterranean fires.

The formation of the acids, the oxydation of the metals, the decomposition of the bitumens, and all the phenomena of oxydation or combustion which take place in the bowels of the earth, wherever the atmospheric air does not penetrate, could not be accounted for, except by the decomposition of water.

If from the interior of our earth we proceed to its surface, we find that all living beings also owe the exercise of their principal functions to the decomposition of water: vegetables grow by the help of water alone, and this liquid is a necessary vehicle for all the other principles which complete its nutrition.

CHAP. VII.

Of the Combinations of Sulphur.

SULPHUR is one of the most powerful means of chemical action : we find it combined with almost all the metals : it is easily dissolved in hydrogen, and assumes in this combination a character of volatility, by the help of which it acts upon all bodies, and produces phenomena as various as they are important. It easily unites also with oxygen, and forms with it an acid, which is combined with the earths and metals, and produces that numerous variety of sulphats which nature presents to us almost every where.

We shall here speak of its principal combinations only, and particularly of those which are most used in the arts.

SECTION I.

Of the Combination of Sulphur with the Alkalies.

If we melt potash or soda in a crucible with equal parts of sulphur, there results a hard and greenish mass, almost without smell. This sulphuret strongly attracts humidity, and is reduced into liquid; it then exhales a striking smell of sulphuretted hydrogen gas. We may expect to preserve the sulphuret of potash in the dry state by keeping it in well corked bottles.

But if in place of presenting the alkalies in the dry state, we dissolve them in water, and digest them warm over sulphur, the solution instantly takes place, the liquor assumes a tint of reddish yellow, more or less deep, and it exhales a smell of sulphuretted hydrogen gas.

When this hydro-sulphuret of alkali comes in contact with the air, it deposits a considerable quantity of sulphur; the smell disappears, the liquor clears off, and it no longer contains

any thing except sulphate of potash or solution.

In all the cases we have mentioned, the production of the sulphuretted hydrogen gas, and that of the sulphuric acid, are owing to the atmospheric air, or to the decomposition of water, the two constituent principles of which act upon the sulphur, and form with it sulphuretted hydrogen gas, which escapes into the atmosphere, and sulphuric acid, which seizes upon the alkali. In proportion as the alkali is combined, the greatest part of the sulphur is precipitated, because the formation of sulphuretted hydrogen gas, and that of sulphuric acid, can only employ a part of that which was dissolved in the alkali.

The sulphuret of ammonia does not present the same characters with that of the fixed alkalies. In order to form it, we carefully mix in a marble mortar three pounds of slaked lime, one pound of sal ammonia, and eight ounces of sulphur. This mixture is put into a retort; six ounces of water are added, and we proceed to distillation. The first drops which pass over are colourless; but they afterwards become of a citron yellow. As soon as about six ounces

of liquid have passed over, very elastic white vapours, almost incoercible, are raised; the fire must now be managed so as to prevent an explosion; it is kept burning an hour longer, increasing it always when the vapours become less abundant. We extract by this means about four ounces of sulphuret of ammonia, which is known by the name of smoking liquor of Boyle.

Hoffman employed no water, and made use of quick lime; but by this process the sulphuret is not abundant, although very smoking, and so elastic, that an explosion often takes place in the distillatory vessels.

M. Berthollet has shewn that the sulphuret of ammonia owes the property of being smoky to a mixture of uncombined ammonia. This sulphuret of ammonia may be charged, even in the cold, with a much greater quantity of sulphur, and it then ceases to be smoking. This sulphuret saturated with sulphur is of a dark colour and an oily consistence; at least, on exposure to the air, it becomes white, turbid, and abandons the sulphur.

As the ammonia alone does not dissolve the sulphur, we see that it is by mea

sulphuretted hydrogen that the triple combination is formed, and that it then receives the name of hydrogenated sulphuret of ammonia; while when the combination is smoking, it may be named sulphuretted hydrogen, with an excess of ammonia.

The sulphurets of alkali are not much employed; they have been prepared for being applied to the eudiometrical methods. But the sulphuretted hydrogen, which is mixed with the air we wish to analyse, renders this method less exact, and of more difficult execution than when we employ bodies which take up oxygen, and do not mix any volatile principle with the air upon which we operate.

SECTION II.

Of the Combination of Sulphur with the Earths.

After having well mixed one pound of quick lime in fine powder, with four ounces of flowers of sulphur, if we pour water upon the mixture, as if to slake the lime, and form a soft paste, the heat produced is sufficient to operate

the solution of a portion of lime by the sulphur; and we may separate, by the filter, a yellow liquor which has the smell of sulphuretted hydrogen gas.

We may also form a hydro-sulphuret of lime by diluting that earth in distilled water, through which we pass the sulphuretted hydrogen gas.

Pure magnesia thrown into water charged with sulphuretted hydrogen is dissolved in it.

If we evaporate a recent solution of a sulphuret of barytes, a confused kind of crystallization is formed; these crystals, when submitted to the action of a press in paper, which takes the liquid from them with which they are imbibed, present a white substance, which is the hydro-sulphuret of barytes; the liquor, which is separated, is a sulphuret of barytes, which still retains a great deal of sulphuretted hydrogen.

When we prepare the sulphuret of barytes, there is a much greater proportion of sulphuretted hydrogen formed than in the other sulphurets, because the affinity which the barytes has for the sulphuric acid, determines a more rapid oxydation of the sulphur and the hydrogen. The quantity of sulphuretted hydrogen

formed in each kind of sulphuret is in proportion to the affinity of the bases for the sulphuric acid.

SECTION III.

Of the Combinations of Sulphur with the Metals.

M. Berthollet, with his usual sagacity, distinguishes the combinations of sulphur with the metals, from those which are formed with their oxyds.

In the first case, the sulphuret attracts oxygen from the atmosphere, or rather it remains without alteration or change, according to the affinity of the metal for oxygen, according to the affinity of sulphur for the same principle, and according to the tendency which metal itself has to combine with the sulphuric acid, which must be the result of the oxydation of the sulphur.

Thus iron combined in the metallic state with sulphur, forms a black sulphuret, very fusible in the fire; and when it is combined in the state of an oxyd, it forms a yellow sulphuret, less fusible, and of more difficult decomposition.

The black sulphuret of iron becomes yellow in the air, in consequence of the oxydation of the two component principles, and is changed into sulphate.

The action of the acids upon the metallic sulphurets is very different, according as the metal is in the metallic or oxyd state: in the former case, the acids, which are easily decomposed over the metals, and thus pave the way for their solution by oxydating them, act speedily; in the second case, the acids, which are not decomposed, exert the most energetic action.

It follows from the experiments of M. Berthollet, that sulphuretted hydrogen is combined with some metals, but particularly with the oxyds; and that the concentrated acids seize upon these oxyds, and eliminate from them the sulphuretted hydrogen.

In most of the hydro-sulphurets formed by the metallic oxyds, the tendency which hydrogen and oxygen have to combine, occasions the decomposition of the sulphuretted hydrogen.

The hydro-sulphuret may be decomposed either by giving its hydrogen, or 1

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giving up the sulphur to the oxygen; this varies in a singular manner the results of these decompositions.

When the metals are brought by this de-oxygenation to a state approaching the metallic, they refuse to combine with the acids; hence it follows, that the black precipitate of mercury, that of silver, and a part of that of copper, resist the action of the acids.

The gradual de-oxygenation is very sensible when we form a solution of sulphuretted hydrogen in a solution of corrosive sublimate of mercury: at first the precipitate formed is yellow; the colour darkens as we add the sulphuretted hydrogen, and becomes black.

The oxyd of manganese takes sulphuretted hydrogen from water; it eliminates the ammonia from the sulphuretted hydrogen of ammonia; its action upon this last substance is accompanied by so great a degree of heat, that the liquor boils: thereby it loses its colour; it becomes soluble in water on taking an excess of sulphuretted hydrogen, and we may precipitate it in this state in a white form by an alkali.

ARTICLE I.

Of the Combination of Sulphur with Mercury.
(*Cinnabar, Ethiop's Mineral.*)

The combination of sulphur with mercury, forms *ethiop's mineral*, and *cinnabar*.

The first of these two compounds is of a black colour; but its fracture and the trituration of the masses produce a deep red colour.

The second is of a very brilliant red colour, which also increases by trituration; in this state it is called *vermilion*.

We may form *ethiops* in different ways: 1. By tritulating in a mortar four ounces of mercury and twelve ounces of sulphur; 2. By pouring one ounce of mercury upon four ounces of melted sulphur, the mixture inflames, the flame is smothered and the crucible is taken off the fire: 3. By mixing a solution of sulphuret of potash with a solution of nitrate of mercury.

Those *ethiops*, when combined, bar; but as it is difficult to give it laboratories, that liveliness of colour

racterise the cinnabar in common, we shall describe, according to Messrs. Luckert and Payssé, the processes adopted in Holland.

They mix 150 pounds of sulphur with 1080 pounds of mercury; the mixture is put into a flat iron caldron, and a gentle heat is produced under it, capable of holding the sulphur in a state of liquefaction, and facilitating the solution of the mercury.

They pound the sulphuret of mercury thus prepared, and small earthen pots are filled with it of the capacity of 24 ounces of water each.

They sublime in a species of crucibles well luted, round which the flame circulates. The aperture of each subliming vessel is about a foot diameter.

As soon as these vessels are fixed upon the furnace, they kindle a moderate fire, which is increased until the vessels become red hot; they then pour sulphuret of mercury into each; a flame afterwards rises, the disengagement of which is very rapid, and the colours very variegated, at first of a lively white, afterwards yellow and white, orange yellow, and blue and yellow; when the flame has slackened, and the colour is of a fine indigo blue, the vessels

are closed hermetically with plates of iron an inch and a half thick. This first operation lasts 34 hours.

The fire is continued for 36 hours, managing it in such a manner, that upon taking off the lid the flame is found to be brisk, without rising higher than three or four inches. Below or above this medium the fire is too weak or too strong. It is fed by turf.

During the 36 hours that the sublimation lasts, the mass is stirred every quarter of an hour, or every half hour, with an iron triangle.

After the whole is cooled, the vessels are taken out and broken; in each there is found 400 pounds of sublimed sulphuret of mercury or cinnabar.

It is necessary, in order to obtain a good result, to keep up a constant and moderate heat during the whole time the sublimation lasts.

Mr. Thomson has published the following process for making cinnabar. We are indebted for it to M. Kirchoff.

Take 300 grains of mercury and 60 grains of sulphur, which must be wetted with a drop of solution of potash, and triturated in a porcelain mortar, to reduce them into ethiop's mi-

neral. Add 160 grains of potash dissolved in an equal quantity of water. The vessel is heated by a gentle warmth, and the trituration is continued without interruption. As the water evaporates more is added, and the trituration is continued for two hours; when a great part of the fluid has evaporated, the colour then becomes red. We then cease adding water, but continue the trituration, and when the mass has acquired the consistence of a jelly, the red colour becomes more and more brilliant; the produce assumes an extreme degree of fineness. At this moment the heat must be stopped, in order to prevent the alteration of the colour.

Count Moussin-Pouschkin has proposed to withdraw the substance from the fire the instant it became red, and to expose it to a gentle heat for two or three days, adding a little drop of water, and shaking it from time to time.

Pounded cinnabar forms the *vermilion* of commerce; as the more or less perfect division gives a more or less lively red, care is taken to pound the cinnabar under water, and those parts only are taken which are so minutely divided as to remain suspended in the liquid for

some time. The coarser parts which are precipitated are again pounded, and the operation is continued until the whole is brought to the same degree of tenacity.

In my opinion, if the cinnabar was pounded with the same care in urine, it would yield a vermilion of a much finer colour; I have prepared it several times by this process with great success.

The Chinese supply the Europeans with a finer vermilion than that made by the Dutch; its colour is so beautiful, that the latter have not yet succeeded in giving it the same brilliancy. M. Payssé observed, that by keeping the Dutch vermilion for thirty days under water, and out of the reach of the rays of light, and agitating it occasionally with a glass tube, the colour thereby acquired the greatest beauty. A clear light and the contact of the air discolour vermilion, and change it into a brick red inclining to brown.

M. Berthollet attributes the difference between the *black sulphuret of mercury*, or *ethiop's mineral*, and the *red sulphuret* or *cinnabar*, to the former containing a more or less considerable quantity of sulphuretted hydro-

gen, whereas the latter is a sulphuret without mixture. The former is the hydrogenated sulphuret, the latter is the sulphuret of mercury.

This opinion is confirmed by the observation of what passes in the conversion of the ethiops into cinnabar.

Wallerius relates, that if we boil the black sulphuret with potash, it is changed into cinnabar.

M. Berthollet obtained the same effect by a long ebullition, and employing pure potash.

Beaumé has shewn, that mercury mixed with a solution of hydro-sulphuret of potash, or of ammonia, is reduced into black mercury, and that after a longer or shorter period, the sulphuret is changed into cinnabar. M. Berthollet saw the same effects in employing the mercurial salts.

Nature presents us with sulphurets of mercury completely formed, or native; but their colour, particularly that of the cinnabars, is very inferior to that of similar productions made by art.

Vermilion is used in painting, and cinnabar in medicine. Two parts of cinnabar,

mixed and distilled with one part of iron filings give up the sulphur to the iron, and the mercury passes into the receiver. This mercury, when very pure, is called *revivified mercury of cinnabar*.

ARTICLE II.

*Of the Combination of Sulphur with Arsenic,
(Orpiment, Realgar.)*

The combinations of arsenic and sulphur present a vivacity of colour, which has very much extended their uses in the arts, and has given them the names of *yellow arsenic*, *orpiment*, and *red arsenic*, or *realgar*.

Almost all the sulphurets of arsenic known in commerce are native ones; the neighbourhood of volcanoes furnishes plenty of orpiment and realgar: it is found in great abundance at Solfatara, near Naples.

The metallic, arsenical, and sulphureous ores, contain it also.

Realgar appears more common in China than in any other part of our globe. The Indians make pagodas of it, or hollow it into vessels,

which they use for containing purging medicines, by heating for some time a sour liquor, which they afterwards drink.

Realgar often presents the form of compressed prisms terminated by two tetrahedral summits.

Orpiment is still more common than realgar. That known in commerce comes from some places in the Levant, in irregular, solid, or lamellated masses, which are of a fine citron yellow. M. de Born found it in polyhedral crystals, in a bluish argil from the environs of Newsol, in Hungary.

We may prepare the sulphurets of arsenic by mixing together, and distilling arsenical pyrites and sulphureous pyrites; those two mineralisers are sublimed, and form by their combination orpiment or realgar, according to their proportions, and the degree of fire.

It was for a long time thought, that in order to form realgar, it only required a tenth of sulphur, while it required one fifth to form orpiment, and these proportions have been prescribed for manufacturing both products. But it is now known, that whatever be the pro-

portion of the sulphur, orpiment or realgar is obtained by varying the degree of heat; the realgar is constantly the produce of a stronger heat: this excess of heat volatilizes a portion of the sulphur, and contributes to oxydate the arsenic, and thence it happens, perhaps, that analysis presents from ten to fifteen per cent. of sulphur in the realgar, while Westrumb found 20 of sulphur, 79 of arsenic, 1 of iron, in 100 parts of orpiment. M. Thenard demonstrated, that in orpiment the arsenic is to the sulphur as 4: 3; and in the realgar as 3: 1.

The sulphurets are much employed in painting, on account of the solidity and brilliancy of their colours. They are also used in painting cottons and in dyeing.

These sulphurets have also the advantage of preserving the colours, of keeping them from decomposition and mouldering when they are wetted, and of keeping away moths and other insects.

These sulphurets may be also used in dissolving indigo. Scheffer and Bergmann have proposed mixing six drachms of orpiment with very strong soap-maker's ley, in which three drachms of pulverized indigo have been put

for every pint of liquor. In a few minutes the bath becomes green, throws up a bluish froth, and forms a pellicle; the fire is then withdrawn and the dyeing is begun.

The blue for painting cloths is prepared in a similar manner: M. Haussman of Colmar employs for 200 pounds of water 30 pounds of potash, 12 pounds of quick lime, 12 pounds of orpiment, and 16 pounds of indigo. The liquor is thickened with gum. M. Oberkampff employs a stronger dose of indigo, being one-eighth of the water employed.

Those sulphurets are also used for rendering hard and brittle some of the metals, such as lead, iron, &c. and they are predisposed by this slight alloy for several operations where less ductility is required.

ARTICLE III.

Of the Combinations of Sulphur with Tin (Aurum musicum, or aurum mosaicum).

In order to combine tin with sulphur, the latter must be mixed with the melted metal.]

The sulphuret formed is of a radiating fracture, and very often lamellated, the sulphur according to Bergmann is in the proportion of 20 to 100.

But in order to combine a greater quantity of sulphur with tin, various intermedia must be employed, such as mercury, muriate of ammonia, corrosive sublimate, &c. By this means we succeed in making the sulphur enter in the proportion of 40 to 100; and the sulphuret is of a gold colour, soft to the touch, forming slight and velvet-like scales. This is called *aurum mosiacum*, or *aurum musivum*.

For a long time chemists have employed in its preparation equal parts of tin, sulphur, mercury, and muriate of ammonia. But the Marquis de Bullion has proved that we may diminish the proportions of the sulphur and the muriate, and he has adopted the following process.

Begin by amalgamating 8 ounces of tin, and as much mercury into it; when the metal has acquired a certain degree of heat, melted tin is poured above; this alloy must be shaken and triturated until it is cold; then mix it with 6 ounces of sulphur, and 4 ounces of muriate of ammonia; place this mixture in a

matras, place it on a sand bath, and heat it until the bottom is obscurely reddened; the fine matter must be kept up for three hours. A spongy, light, yellow matter is found in the matras; this matter is sometimes gray. It is called *aurum mustum* when its colour is a fine golden yellow.

If instead of placing the matras in the sand bath, we carefully lute it, and expose it immediately upon burning coals, the mixture is inflamed, and there is sublimed at the neck of the matrass an *aurum mosaicum* in large scales of the finest yellow colour; I have obtained these scales of a hexagonal form by this process.

M. de Bullion has proved that mercury and muriate of ammonia are not necessary for forming *aurum musicum*. Eight ounces of muriate of tin precipitated by the carbonate of soda, and mixed with 4 ounces of sulphur, yielded a fine *aurum mustum*. But this preparation does not excite the electrical machine like the other; which proves that this property is owing to the mercury which enters into the first composition in a very strong proportion.

Pelletier has resumed those experiments, and has added to them some very important facts:

1. Equal parts of tin filings, sulphur and muriate of ammonia, yielded him upon distillation, sulphuret of ammonia, sulphuretted hydrogen gas, a little sulphur and muriate of ammonia; what remained in the retort was very fine mosaic gold. 2. Being convinced that a too violent fire left no residue except sulphuretted tin in a bluish grey mass, he melted in a crucible 100 ounces of tin; he added sulphur gradually, until the tin was saturated; the fusibility of the metal diminishes, in proportion as we continue to mix sulphur with it. The crucible containing the sulphuret is allowed to cool, and on being taken out it weighs 120 ounces.

This sulphuret of tin distilled with the addition of muriate of ammonia, yields no mosaic gold; but it leaves as a residue a black, various coloured, inflated and friable mass, which Pelletier regards as an oxyd of tin imperfectly saturated with sulphur. Six hundred grains of sulphuret, being mixed with equal parts of muriate of ammonia and sulphur powder, give one ounce of fine mosaic gold: 3. Pelletier employs in his operation a wide crucible, which he fills one third only: he introduces into the crucible a lid which

rests about half an inch above the matter, and he covers the whole with a second lid which he lutes carefully. He places this crucible within a large one, and fills up the interstices with sand: he places this apparatus upon the grate of a common furnace, and heats with precaution. In general, in order to have a fine mosaic gold, it must be prepared by a gentle and well kept up heat, at a degree necessary for subliming the sal ammonia, during 8 or 9 hours.

From the numerous experiments published by Pelletier, we may conclude: 1. That mosaic gold is merely a sulphuret of tin: 2. That the oxyd of tin is charged with a greater quantity of sulphur than pure tin: 3. That we may directly combine the oxyd of tin with sulphur even by the humid way: 4. That a too strong heat volatilizes a portion of the produce: 5. That we may re-establish the operation, by adding a new dose of sulphur to the residue.

The beauty and solidity of the colour of mosaic gold, the elegant form of its scales and its lightness, caused it to be employed a long time as an ornament, and it is also used for giving a fine colour to bronze and other matters.

Mosaic gold is used for rubbing the cushions of the electrical apparatus, and it augments its intensity.

ARTICLE IV.

*Of the Combinations of Sulphur with Antimony
(crude Antimony, Liver of Antimony,
Kermes.)*

Antimony unites with sulphur with such facility, that it is only requisite to melt 18 ounces of sulphur, and 16 of antimony, in order to obtain 2 pounds of this metal. But nature presents us with this combination in such abundance, that we may dispense with its preparation: in fact antimony is generally mineralised by sulphur; the first work we execute upon this mineral is confined to melting it in order to separate the foreign bodies from it; there then results a sulphuret of antimony, the texture of which is striated, and formed by a bundle of needles applied strongly upon each other; this is called *crude antimony*.

The sulphuret of antimony has several uses in the arts; it is decomposed in order to separate the metal from it; it is dissolved with the alkalis for forming some medical preparations; it is dissolved also with indigo for composing a blue for the dyers.

It is evident that the first thing that
 was done was to get the names of the
 people who were living in the country at
 that time. This was done by sending out
 agents to visit the different parts of the
 country and to get the names of the
 people who were living there. The names
 of the people who were living in the
 country at that time were written down
 in a list.

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The third thing that was done was to
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 living in the country at that time. This
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 get the names of the people who were
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 time were written down in a list.

The method by the humid way has also received improvements, which make it at present one of the simplest operations in Chemistry.

We prepare a ley of caustic alkali by the known process, and boil it for half an hour upon nearly one fifth of pulverized sulphuret of antimony. The boiling solution is filtered through a cloth, and we obtain by cooling it only an abundant precipitate which requires but to be dried, in order to form the *kermes* of commerce.

We may boil a new quantity of potash over the sulphuret in order to obtain a new dose of *kermes*. But its colour becomes paler, and we cannot give it the ground and colour of fine *kermes*, except by adding a new quantity of sulphuret or sulphur to the composition.

It is sufficient to wash the *kermes* well in cold water, to separate from it all the potash it retains. This alkali is not necessary to its composition.

The liquor from which the *kermes* precipitates upon cooling, when decomposed by the acids, gives a precipitate of a yellow colour, which has been called *gilded sulphur of antimony*.

M. Berthollet has proved that kermes and gilded sulphur were oxyds of antimony, combined with sulphur and sulphuretted hydrogen.

Bergmann extracted from 100 grains of kermes, by means of the muriatic acid, 15 cubical inches of sulphuretted hydrogen gas; and M. Thenard proved that kermes contained :

Sulphuretted hydrogen	20,298
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Sulphur	4,156
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Chesnut coloured oxyd of antimony	72,760
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And that 100 parts of gilded sulphur yielded :

Sulphuretted hydrogen	17,877
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Sulphur	11,730
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Orange coloured oxyd of antimony	68,300
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The same chemist was convinced that kermes absorbed oxygen gas, and that there resulted from it a decomposition and a change of colour, which altered the property of this preparation.

Kermes is one of the powerful remedies in medicine, and it is much to be desired that the most scrupulous attention should be paid to its preparation. It should be kept in close vessels, and out of the reach of all humidity, in order to preserve it free from alteration.

CHAPTER VIII.

Of the Combinations of Hydrogen.

SECTION I.

*Of the Combinations of Hydrogen with Azote
(Ammonia, Volatile Alkali).*

THIS combination forms ammonia, hitherto known by the name of *volatile alkali*.

Ammonia has a very pungent smell without being fetid; it corrodes the skin, or at least reddens and inflames it, when it is concentrated.

It preserves the gaseous state of the temperature of the atmosphere; it is easily dissolved in water, and even with heat, and it is this last property which affords us the means of conveniently concentrating, preserving, and transporting it from place to place.

Ammonia possesses all the properties which characterises the alkalies, and forms, with the

acids, known combinations, some of which are employed in the arts.

It seems that the formation of ammonia is chiefly owing to the decomposition of animal substances; all of them furnish more or less of it: and if we obtain it from some earthy or vegetable substances by distillation, it is because they contain products of an animal nature.

We may therefore extract ammonia from the animal substances, and we employ for this purpose, distillation or putrefaction; in both cases, the two principles which constitute it unite, by disengaging themselves from the bodies where they exist separately.

Horns are the animal parts which furnish most of it; the produce is known generally by the name of *volatile spirit of hartshorn*. I have distilled the larva of some insects, particularly those of the silkworm, when the butterfly has come out of them, with as much success as horns.

But the ammonia, extracted by those methods, is never pure; it is mixed with oil and other principles, which alter its properties. It is only after repeated distillations, and by the

intermedium of earths, that we can free it from foreign substances.

It is this difficulty of obtaining ammonia pure and exempt from all smell of animal oil, that has suggested the decomposition of the muriate of ammonia, by means of quick-lime.

For this purpose we mix equal parts of sifted quick-lime, and well-pounded muriate of ammonia; the mixture is afterwards introduced into the retort, to which a receiver and Wourn's apparatus are adapted. We distribute in two flasks a quantity of water, corresponding to the weight of the salt employed; the junctures of the vessels are luted with common luting, which is fastened with a wet bladder, or pieces of linen covered with luting made of lime and whites of eggs.

Care is taken not to heat the apparatus until the luting is very dry.

The ammonia passes in the state of gas on the first impression of the fire; it is dissolved in water with heat, and saturates it.

It is this water, impregnated with ammoniacal gas, which has been called *ammonia*, *volatile alkali*, and *volatile spirit of hartshorn*.

In some manufactories where this salt is

prepared on a large scale, the muriate is mixed with the lime and the water necessary, and the ammoniacal vapour is condensed in receivers surrounded by refrigerators. This process requires less care, and exposes the workmen to less danger than the foregoing; those vapours are infinitely less expansible than the gas, when it is dry.

Water, saturated with ammoniacal gas, may mark 28 degrees in Beaumé's areometer; but the alkali of commerce is not concentrated, except at 22 or 23 degrees.

Heat and shaking will produce the explosion of the vessels, when the ammonia is more concentrated.

The constituent principles of ammonia are very well known to us at present. The experiments of Priestly, who, by means of the electrical spark, converted ammoniacal into hydrogen gas, had already given us reason to believe, that hydrogen was one of its elements, but it was reserved to M. Berthollet to convert our presumptions into certainties, and to prove to us that hydrogen was combined with azote in the ammonia. We shall collect the different proofs with which this experienced

chemist has furnished us; and add to them those which M. Fourcroy has drawn from his own experiments, in order to establish this important discovery.

1. If we mix oxy-muriatic acid with very pure ammonia, there is an effervescence, disengagement of azotic gas, production of water, and conversion of the oxy-muriatic acid, into common muriatic acid.

Here the hydrogen of the alkali combines with the oxygen of the acid to form water, while the azote and muriatic acid become free.

The oxy-muriatic acid gas passed through liquid ammonia, is decomposed.

If, instead of employing the solution of ammonia in water, we make the ammoniacal gas pass under a bell-glass inverted over mercury, and introduce into it oxy-muriatic acid gas, a brilliant white flame is immediately produced; a very thick smoke at the same time obscures the whole capacity of the bell-glass; a very considerable quantity of caloric is liberated, and in a few minutes, the sides of the bell-glass, which before were dry, are covered with streaks of water, which flow down and collect upon the surface of the mercury.

When, in this last experiment, the proportions are proper for completely decomposing the oxy-muriatic acid, we only find azotic gas, and some atoms of muriatic acid in the water which is formed.

2d. The distillation of the nitrate of ammonia furnishes azotic gas and water. The oxygen of the acid, and the hydrogen of the alkali, produce this liquid.

3d. When we pour ammonia upon a solution of sulphat of magnesia, the oxyd of the metal is precipitated in the form of brown flakes, which are soon separated from each other, and are agitated by bubbles of an elastic fluid, which raises them to the surface of the liquor. The gas disengaged is that of azote.

4. The mercury, precipitated from the nitrate by the same process, presents the disengagement of a similar gas.

5. The nitrate of iron, decomposed by ammonia, presents a black oxyd, from which is disengaged gradually a crowd of small bubbles of azotic gas. The oxyd becomes brown.

6. If we sprinkle the oxyd of manganese with ammonia, a slight effervescence is pro-

duced, at the temperature of 10 or 12 degrees of Reaumur, and the oxyd passes slowly to the grey or white colour. The effervescence is owing to the azotic gas; and we may increase and accelerate the production of it by raising the temperature.

The same effect takes place between the brown oxyd of iron and ammonia; the effect is speedier with the oxyds of mercury.

When, by the simple contact of oxy-muriatic acid gas, the surface of the mercury has been oxydated, it is sufficient to lay over this oxyd, a feather dipped in ammonia, in order to recal it to the volatile state.

The oxyds of lead, zinc, cobalt, bismuth, and antimony, are less proper for decomposing ammonia; nevertheless, if we digest *liquid ammonia*, over *litharge*, azotic gas is disengaged, and the oxyds of bismuth and cobalt undergo some changes by the action of this substance.

I have observed myself that ammonia, digested with the white oxyd of arsenic, is decomposed, and that the oxyd is reduced to the state of metals; which crystallizes in octahedrals.

The decomposition of ammonia already shews sufficiently that it is composed of hydrogen and azote; but the process which we may draw from its formation, places this doctrine beyond all doubt.

1. M. Berthollet has shewn that wherever there is azote and hydrogen, ammonia is constantly produced; that the animal parts furnish so much the more of it the more they are provided with azote; and that by depriving them of this principle, we take from them the power of furnishing it; that this formation only takes place at the moment when these two principles become free by putrefaction; that ammonia does not exist in living and healthy animals.

2. M. Kirwan saw ammonia formed by the mixture over mercury of sulphuretted hydrogen gas and nitrous gas.

3. When we decompose nitric acid over copper, iron, or oils, we distinguish by the smell the formation of a little ammonia, particularly when the decomposition is rapid.

4. In 1788, Mr. William Austin communicated to the Royal Society of London, a course of very interesting experiments upon the form-

ation of ammonia, from which we may conclude that the composition of hydrogen and azot cannot take place while both are in the state of gas; that, if we decompose water over iron in flasks filled with azoted gas, as fast as the hydrogen is liberated it combines with the azote, and forms ammonia; that if, instead of employing azotic gas we employ nitrous gas, the formation of the ammonia is speedier, and in this case the nitrous gas is so deprived of azote, that a candle may burn in it with more facility than in common air, as Priestly has already remarked.

According to M. Berthollet, the proportion of azot to hydrogen is as 121 to 29, and according to Austin's calculation, as 121 to 32.

Ammonia is used in medicine as a stimulant, and it is one of the most energetic we know. It is also employed as a drink, in the dose of a few drops diluted in water, when we wish to determine the humours towards the skin.

Ammonia is also used in the arts, where it has been for some time used to quicken some colours, particularly those upon paper, and to shade some colouring principles upon silk.

It dissolves the oxyd of copper precipitated

from the sulphates, the nitrates, the muriates, &c. ; and this solution, which is only a triple salt, takes a fine blue colour, which, when properly concentrated, makes a fine appearance upon paper.

The principal combination of ammonia is that which it contracts with the muriatic acid : of this we shall speak afterwards.

SECTION II.

Of the Combinations of Hydrogen with Phosphorus.

Phosphorus may be dissolved in hydrogen gas; and it takes fire at the temperature of the atmosphere in this state of solution.

M. Gengembre, on the 3d of May, 1785, read to the Academy of Sciences a memoir, in which he proposed to extract phosphoretted hydrogen gas, by digesting the alkalies over phosphorous.

M. Raymond some time afterwards made known, that by mixing two ounces of slaked lime with one drachm of phosphorus cut into small pieces, and half an ounce of water, and

forming the whole into a soft paste, which is hastily put into a stone retort, to which a crooked tube is adapted, inserted under a bell-glass full of water; and if we proceed to distillation, scarcely is the retort heated, when phosphoretted hydrogen gas is liberated, and we may extract three pints of it from the matters employed,

We may use in place of the lime the oxyd of zinc, and the black oxyd of iron; but a violent degree of heat is then necessary, particularly for the composition into which the last of these oxyds enter.

Phosphoretted hydrogen has a great analogy with sulphuretted hydrogen; but they differ essentially by the property the former has of combining with the alkalies, and of forming hydro-sulphurets and hydrogenated sulphurets, while the latter obstinately refuses all combinations with these bases, and neither forms hydro-phosphorets, nor hydrogenated phosphorets. M. Berthollet ascribes this difference to the qualities peculiar to sulphur and phosphorus, sulphur easily combining with the alkalies, while phosphorus unites with lime by a very weak combination only.

When phosphorus is kept in water in close vessels, phosphoretted hydrogen is formed until the water is saturated with it ; it therefore decomposes water in the cold.

Phosphoretted hydrogen takes fire on the simple contact of the air. This phenomenon is owing to the extreme division of the phosphorus dissolved in the gas, and to the affinity of oxygen for hydrogen and the phosphorus itself. Its affinity for hydrogen seems stronger than that which it has for phosphorus ; for if it is not in a quantity sufficient for forming the two combinations, water is at first formed, and the phosphorus is precipitated. We observe the same result, if instead of employing the oxygen from the atmospheric air, we operate with the oxy-muriatic acid gas.

Phosphorus seems to have more affinity for hydrogen gas than sulphur has ; for if we combine without water, sulphur and phosphorus, and then throw the combination into water, it swells up, and phosphoretted hydrogen gas is extricated, which proves that it is the phosphorus which decomposes the water. It cannot be doubted that in this operation, the decomposition of the water is favoured by the

affinity of the sulphur for oxygen; so that the two principles of the water are at once attracted by two bases, with which they form an inflammable body and an acid.

Although phosphorus exposed to the air is dissolved in azotic gas, as M. Berthollet has shewn, instead of being combined with oxygen, there is nevertheless a very marked affinity for the latter substances, particularly when it is in a proper state of condensation: it takes it from the metallic oxyds, according to the observation of M. Sage.

M. Gengembre ascribes to phosphoretted hydrogen gas a specific gravity nearly double that of oxygen gas.

He observed, as well as Kirwan, that this gas is dissolved in water; M. Berthollet has estimated at one-tenth the quantity of gas which might be thus dissolved; M. Raymond has asserted, after all these chemists, that it may be totally dissolved in four parts of water deprived of air; but he adds, that this solution is decomposed by the contact of the air, precipitating a little phosphorus, while it is preserved without alteration if we deprive it of the contact of the air. As this gas takes fire in the open air, ad-

vantage has been taken of this property for procuring a light when we please, and in any place whatever ; it is only requisite to keep it away from the air, and only to expose it when it is wanted, and to determine the inflammation of the bubbles of air which was brought into contact with it.

SECTION III.

Of the Combinations of Hydrogen with Sulphur.

The celebrated Scheele, previous to the year 1775, obtained sulphuretted hydrogen gas by digesting sulphur in a retort filled with hydrogen gas. He concluded from this experiment, that *this sulphureous inflammable air seemed to be a compound of heat, phlogistic and sulphur*, or in other words, sulphur and hydrogen, because he regarded hydrogen gas as composed of phlogistic and heat.

M. Gengembre confirmed this fact, and obtained sulphuretted hydrogen gas by dissolving in hydrogen, by means of the burning lens, sulphur inclosed under a bell-glass filled with this gas. This chemist proved that phospho-

rus was susceptible of a similar solution ; and that in all cases where this combination was formed by the mixture of an alkali with sulphur or phosphorus, the production of the gas was owing to the decomposition of the water, from which the hydrogen dissolved a part of sulphur or phosphorus, while the oxygen saturated another portion of it, and formed a produce which was combined with the alkali.

We may also obtain sulphuretted hydrogen gas by other methods :

1. By distilling sulphur with charcoal or other vegetable substances, such as sugar, the oils, &c., the sulphur is combined with the hydrogen, which exists completely formed in these substances.

2. By passing hydrogen gas through melted sulphur.

3. By decomposing the metallic sulphurets by the combined action of air and water.

4. By dissolving in water, or by humecting with this liquid an alkaline sulphuret.

5. But the process the most frequently used in our laboratories, for obtaining this production in great purity and abundance, consists in melting one part of sulphur in an iron spoon,

and carefully mixing with it, while melting, three parts of iron filings. The mixture is carefully stirred, and it ends by taking fire: the spoon is then taken off the fire, and we continue to stir the mixture with an iron spatula, until the flame is extinguished: a black powder remains, which, upon being decomposed by weak sulphuric acid, the action of which may be assisted by some degree of heat applied to the vessel containing the mixture, produces a great quantity of sulphuretted hydrogen gas.

I have observed that in some circumstances, the gas extracted by this process did not exhale that smell of rotten eggs which characterises it, although in other respects, it had all the other properties belonging to it. It was sufficient for me to assist its extraction by a stronger heat, in order to give it its putrid smell.

Sulphuretted hydrogen gas has a specific gravity, which is to that of the air, according to Mr. Kirwan, as 10,000 to 9,050. M. Theuard found that it contained in 100 parts, 70,857 of sulphur, and 29,143 of hydrogen.

Water saturated with sulphuretted hydrogen gas reddens turnsole tincture, and that of radishes.

Sulphuretted hydrogen is combined with the alkalies, and forms hydro-sulphurets, some of which may be crystallized; M. Berthollet has shewn us the crystallization of the hydro-sulphuret of barytes, and M. Vauquelin has described that of the hydro-sulphuret of soda.

Sulphuretted hydrogen decomposes soap, and unites with the alkali. It precipitates in a great part the sulphur from the solutions of sulphuret of potash and lime, and tends to form with these bases, treble combinations.

The properties of sulphuretted hydrogen make it resemble the acids so much, that it may be comprised in that class; and in this case, the denomination of *burned bodies*, will no longer suit all the acid bodies.

Sulphuretted hydrogen gas dissolved in water is not decomposed by atmospheric air at the common temperature, and in the gaseous state: this results from the experiments of Messrs. Berthollet and Kirwan; in this case the oxygen gas dissolves it and shares it with the water: but it is not the same, when this gas is combined in a hydro-sulphuret, because then it does not any longer oppose to the oxygen gas the resistance of its elasticity.

The hydro-sulphurets are colourless; but they become yellow in contact with the air: if we decompose a colourless hydro-sulphuret by an acid, the gas is liberated without any molecule of sulphur being deposited; while if the hydro-sulphuret has acquired a colour, a deposit of sulphur is formed, which is in proportion to the alteration the sulphuretted hydrogen has undergone.

It would seem, therefore, that in the act of decomposition of the sulphuretted hydrogen, the constituent principle of a hydro-sulphuret, the oxygen at first acts upon the hydrogen; and that soon afterwards, a portion of sulphur is changed into acid, considering that the affinity between the cases which constitute it, increase in proportion as the hydrogen is diminished. It is thus that we see the sulphurets of iron resist the action of the acids, even that of oxygen gas; but, from the instant, that by combustion we have diminished the proportion of sulphur, and increased the oxydation of the iron, the oxygen joins the sulphur which remains, and forms an acid which dissolves the metal.

Sulphuretted hydrogen gas is susceptible of taking sulphur in superabundance, and forming *hydrogenated sulphur*.

When we mix a considerable quantity of muriatic acid with the solution of a hydrogenated sulphuret of alkali ; and particularly when we form by degrees, the solution of hydrogenated sulphuret, into the acid, little sulphuretted hydrogen gas is extricated ; but while the greatest part of the sulphur is separated, there is a proportion of it which is combined with the sulphuretted hydrogen, assumes all the appearance of an oil, and is gradually deposited at the bottom of the vessel. This is what M. Berthollet has called *hydrogenated sulphur*.

This hydrogenated sulphur liberates a little sulphuretted hydrogen gas as soon as it undergoes a little heat or the contact of the air ; and gradually the hydrogenated sulphur loses its fluidity, and finishes by becoming plain sulphur.

When we mix potash with hydrogenated sulphur, a little heat is produced ; and there is liberated from the part that does not combine with the alkali, a small quantity of sulphuretted hydrogen gas. The rest is combined with the alkali, and forms a hydrogenated sulphuret of potash.

When we burn the sulphuretted hydrogen

gas, almost all the sulphur is precipitated from its solution without being decomposed.

The same phenomenon takes place in sulphureous waters, the surface of which, and their pipes, are covered with deposits of sulphur, because the mixture of the sulphuretted hydrogen gas with the atmospheric air, undergoes a true combustion where there should follow a formation of water and precipitation of sulphur.

We may recognize by the sulphuretted hydrogen, and by the alkaline hydro-sulphurets, the smallest quantity of metal which exists in any solution. For, as all the metals, oxyd of arsenic excepted, are precipitated by a hydro-sulphuret, while the earths are not, (if it is not alumine which may be resumed by the potash) we may, after having dissolved by an acid all that is soluble in a compound mineral substance, immediately produce the separation of the earthy and metallic parts.

Sulphuretted hydrogen gas attaches the metals with extreme facility ; it makes them pass to the state of sulphuret, all the characters of which they assume.

When the metals are in the state of oxyds,

their sulphuration is still more speedy by the simple contact of sulphuretted hydrogen gas. The whole oxyds become blackish in a moment.

It seems that the facility with which hydrogen dissolves sulphur is the principal method which nature employs to displace this mineral body, to bring it into new combinations, to mineralise, and, as it were, to fix the metals when altered or passed to the state of oxyds, &c.

SECTION IV.

Of the Combinations of Hydrogen and Carbon.

Carbon is almost inseparable from hydrogen: that which has undergone the most violent degree of fire still contains it, and experience has proved to us that it is almost impossible to free it of it completely: on quickening, by a blast of atmospheric air or oxygen gas, charcoal the most strongly heated, a flame is produced which announces the engagement and combustion of hydrogen.

Lavoisier calculated at one eighth the quan-

tity of hydrogen contained in common charcoal.

Calcination deprives charcoal of part of its hydrogen; but we do not know the term of heat which is necessary to deprive it of it completely. M. Hassenfratz, on passing oxygen through a red-hot tube in which strongly calcined charcoal was placed, saw that water was formed; and the carbonic acid which is produced at the same time, deposits another portion of water.

Mr. Cruickshank remarked, that when we heated a mixture of a metallic oxyd with strongly calcined charcoal, a little water is always liberated.

While the carbon is in a proportion sufficient for giving its character to the combination, the compound is black, solid, infusible, very fixed, and preserves the form of the charcoal; but when the proportion of carbon only forms two thirds of the combination, the compound then assumes the character of the gases, and becomes inflammable, very elastic, &c.

There are, therefore, two distinct states in the combination of carbon with hydrogen; the one in which a fixed compound is observed;

the other, in which it presents a volatile compound. In the one, the carbon gives its character to the hydrogen; in the other, it is the hydrogen which gives it to the carbon.

Between the substances which is the most fixed, the most infusible, and the least alterable in close vessels, which is charcoal; and that substance which is the lightest and most expansible, which is carburetted hydrogen gas, there merely exists a difference of proportions among the principles.

The immense interval between carbon and hydrogen gas, is filled up by infinite shades or intermediate degrees, the number of which cannot be calculated.

It is this variable state in the proportions which occasions the difference of the effects produced by the carburetted hydrogen gases.

The putrefaction of vegetables, marshes, and of the plants and animal matters, are so many operations which produce carburetted hydrogen gas.

M. Berthollet has determined the proportions of the constituent principles of some of them, always neglecting the differences which

may proceed from variations of temperature and taking 100 cubical inches of each.

1. The gas extracted by distilling 4 parts of sulphuric acid and one of alcohol, and which the Dutch chemists have denominated *olefying gas*:

1,560 of carbon

0,520 of hydrogen.

If we pass it through a red-hot tube, a little of its carbon is deposited, and it is now composed of

0,572 of carbon

0,312 of hydrogen.

2. The gas which comes from the alcohol passed through a red hot tube, gives

0,780 of carbon

0,260 of hydrogen.

3. The various gases extracted by the distillation of the oils vary according as the distillation is more or less advanced; that which comes over first is less charged with carbon, and it contains

1,144 of carbon

0,260 of hydrogen.

4. The gas furnished by the decomposition of water over charcoal, contains

0,260 of carbon

0,208 of hydrogen.

Thomson, in his most excellent *System of Chemistry*, has given us the proportion of the hydrogen and the carbon in the principal carbureted hydrogens.

1. That which is extracted from stagnant waters, from ether, from camphor, and the vegetables, contains most charcoal.

Its specific gravity is to that of common air as 2 to 3, and 100 parts, according to Cruickshank, contain

52,35 of carbon

9,60 of hydrogen

38,05 of water in steam.

2. The carbureted hydrogen extracted from wet charcoal by distillation, is the richest in carbon.

100 parts of it yield

28 of carbon

9 of hydrogen

63 of water.

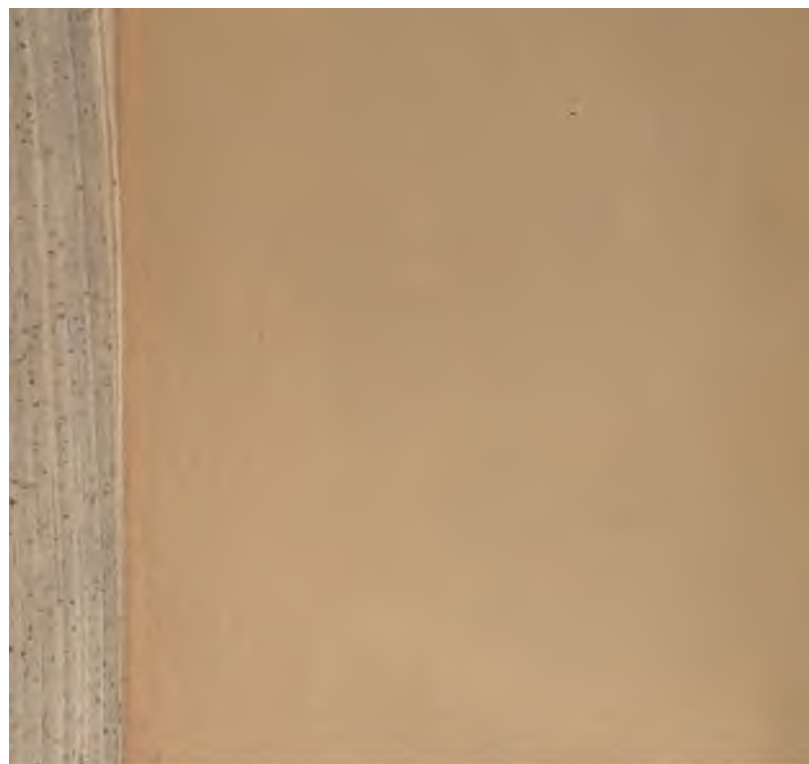
3. The carburated hydrogen from ether furnishes

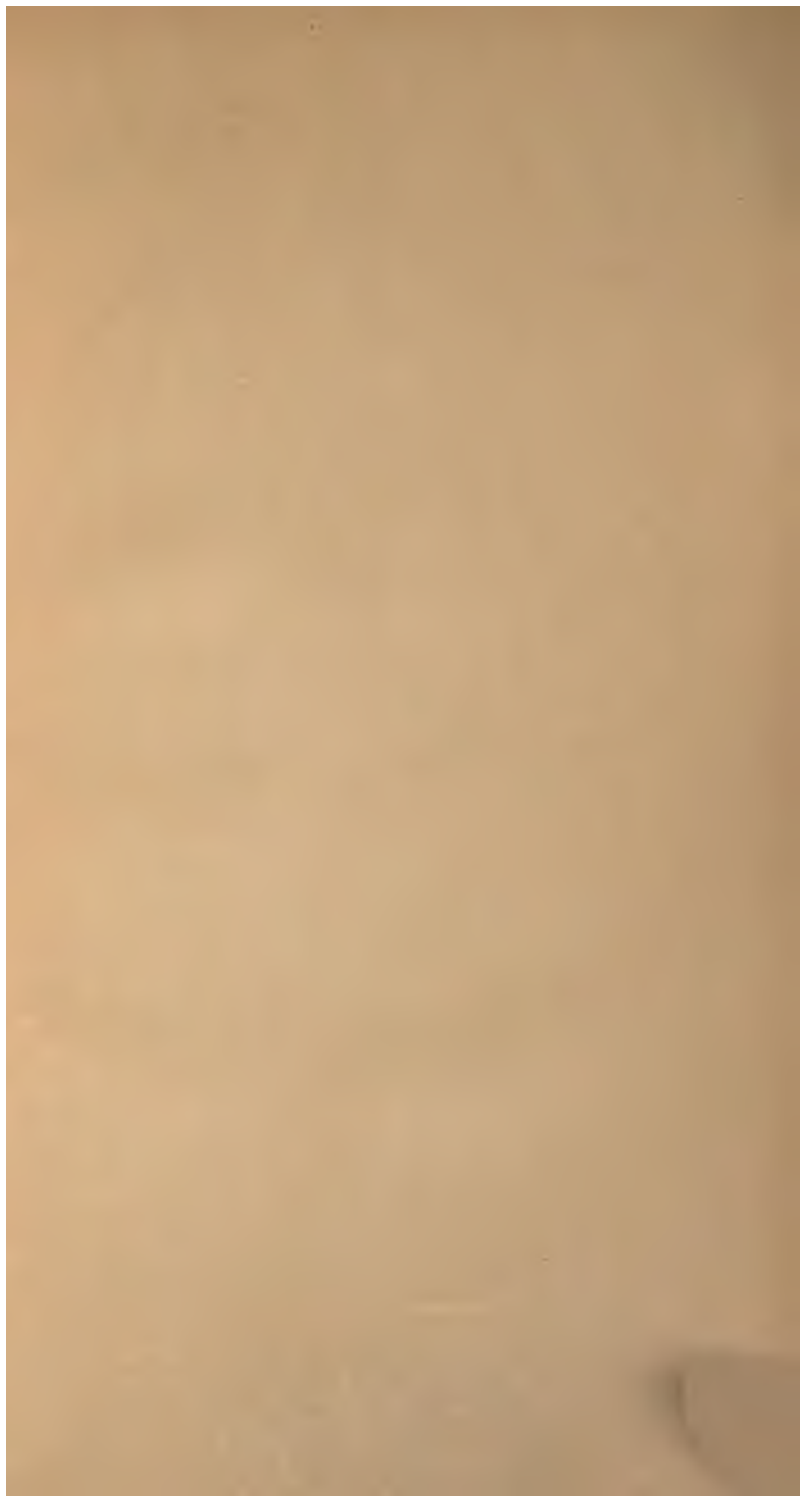
45 of carbon
15 of hydrogen
40 of water.

4. That of spirit of wine
44,1 of carbon
11,8 of hydrogen
44,1 of water.

END OF THE THIRD VOLUME.









MAR 15 1943

